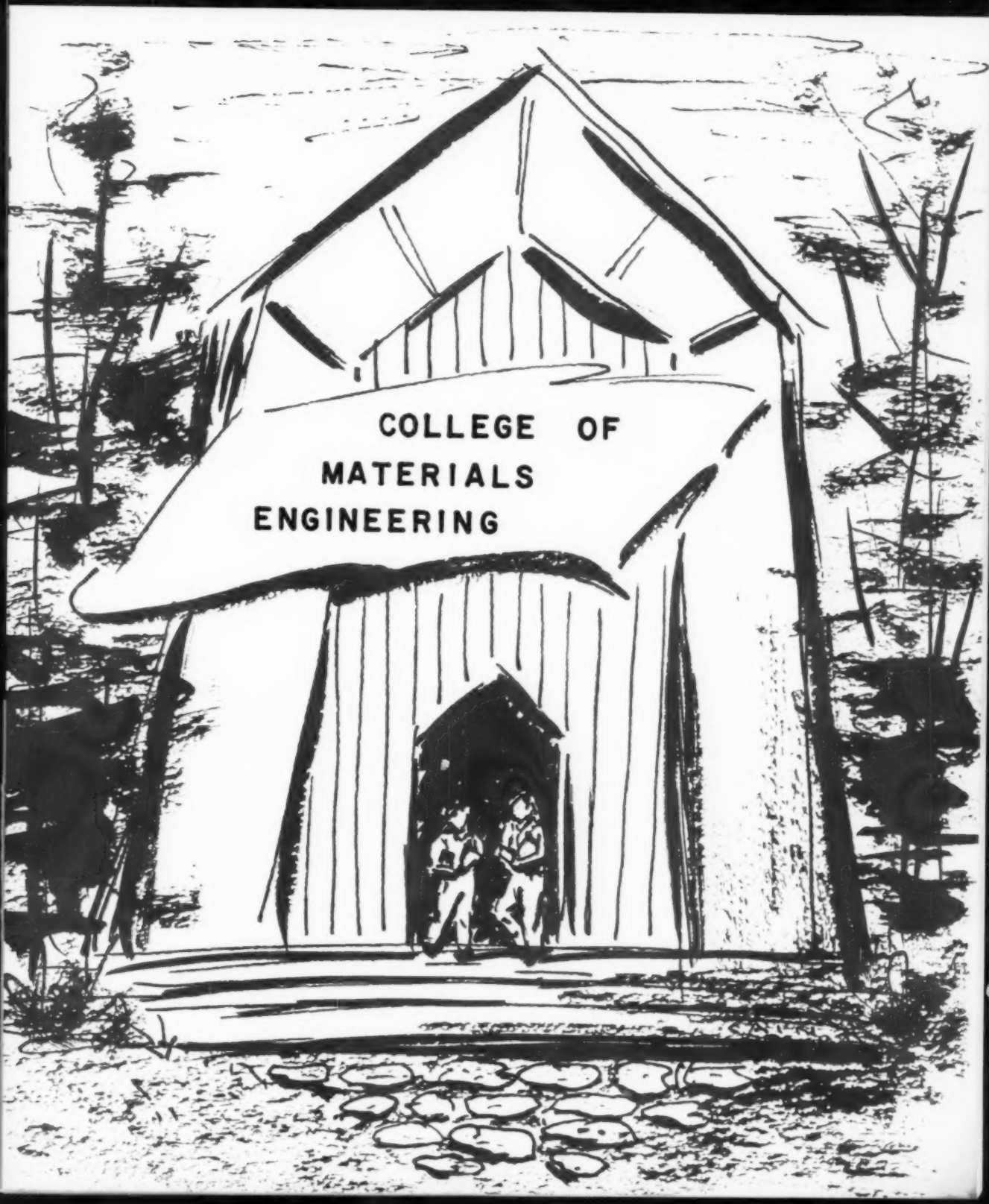
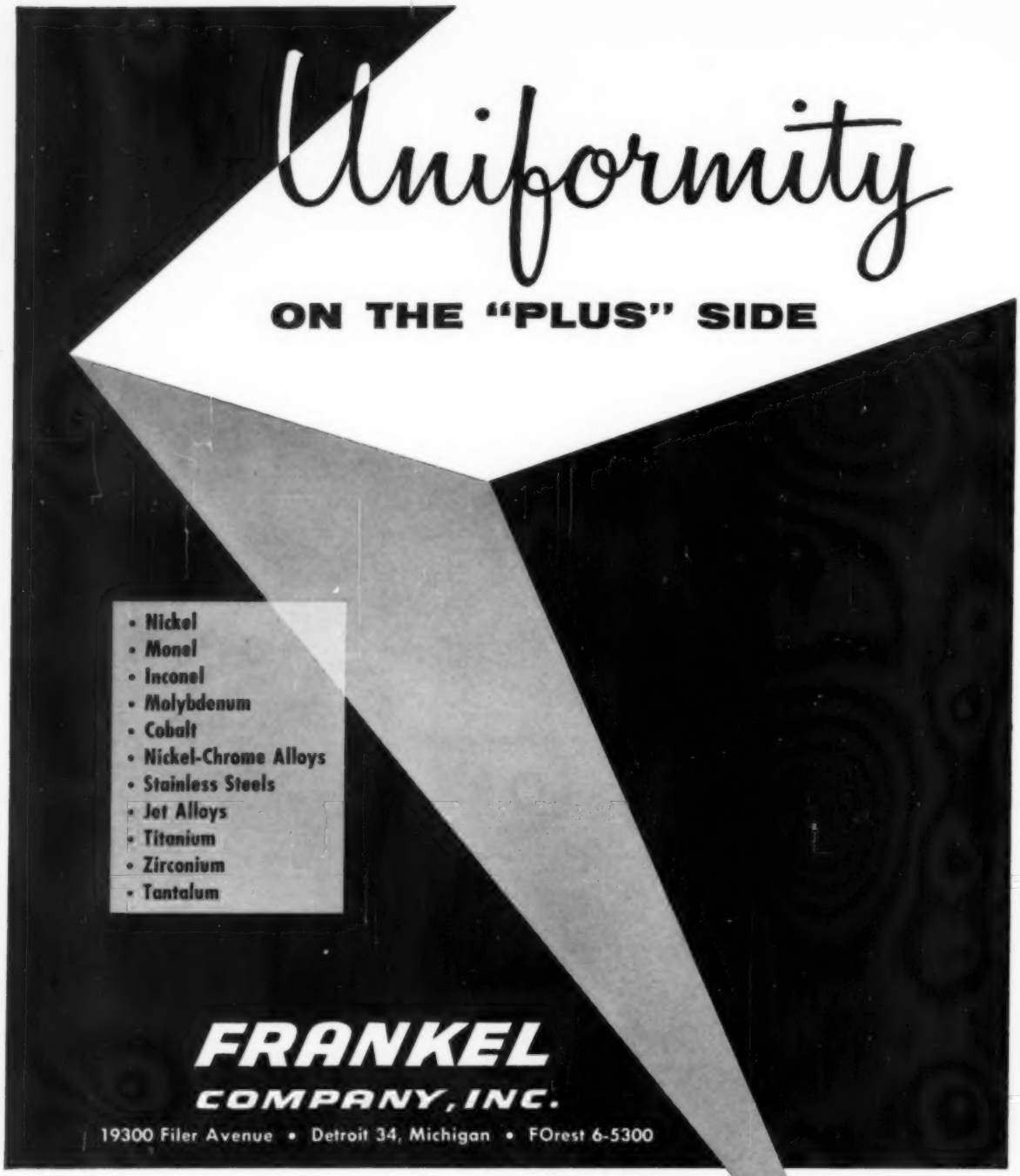
JOURNAL OF

METALS

OCTOBER 1959





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JOURNAL OF

METALS

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October, 1959

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MATERIALS ENGINEERING AND METALLURGICAL EDUCATION

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PERSONNEL

► These items are listings of the Engineering Societies Personnel Service, Inc. This Service, which cooperates with the national societies of Civil, Electrical, Mechanical, Mining, Metallurgical, and Petroleum Engineers, is available to all engineers, members and non-members, and is operated on a nonprofit basis. If you are interested in any of these listings, and are not registered, you may apply by letter or resume and mail to the office nearest your place of residence, with the understanding that should you secure a position as a result of these listings you will pay the regular employment fee of 5% of the first year's salary if a non-member, or 4% if a member. Also, that you will agree to sign our placement fee arrangement which will be mailed to you immediately, by our office, after receiving your application. In sending applications be sure to list the key and job number.

When making application for a position include eight cents in stamps for forwarding application to the employer and for returning when possible.

—MEN AVAILABLE—

All those listed under "Men Available" have membership in the AIME.

Plant Superintendent; B.S. Met., age 32. Twelve years in foundry as asst. open hearth supt., melting supt., and chief metallurgist. Experience in open hearth, direct arc electric, Detroit Rocker, induction (acid and basic), foundry practice, sands, heat treatment, welding, X-ray, magnaflux, and customer complaints. Working in carbon, low-alloy, stainless, hadfield steel castings; and malleable, grey, ductile and wear-resistant iron castings. Prefer Metropolitan Area. M-987-Chicago.

Aircraft Metallurgist; Physical Chemist, age 33. Two and one-half years in the research, development, material analysis, and adaptation of manufacturing procedures for new alloys and refractory metals with aircraft companies. Two and one-half years as physical metallurgist on research and evaluation on ordnance development. Six and one-half years as asst. supt. metallurgist for basic steel manufacturing $700. Any location. S(M)-342.

Mining Superintendent; ME, age 55. Thirty years experience planning and supervision of production, mine examination, exploration and development programs on mining, petroleum, and metallurgy. $700. Prefer US. S(M)-221.

Process Metallurgist; ChE (Canada), age 47. Seven years as manager responsible for quality of metallurgical engineering for consultants and designers. Twenty years director of research for mine, mill, and smelter. $15,000. Prefer West. S(M)-104.

Research Superintendent; MetE, age 47. Four years experience supervising contract mining, milling, and exploration in manganese mine and mill; 10 years as mill supt. in lead, zinc, and asbestos; 6 years in mining chemicals research with lead, zinc, copper, silver ores. $700. Prefer West. S(M)-1826.

Mill Superintendent; ME, age 36. Four and one-half years as mill supt. of gypsum plant, in charge of operation, maintenance, grinding, acid leaching, and expanding plant. Three and one-half years as plant engineer charge of dock maintenance, budgets, and estimates on gypsum products; 1½ years as instructor in math and machine design. $700. Prefer West. S(M)-554.

Mine Superintendent; ME, age 40. Two and one-half years as asst. supt. of mines, survey, maintenance, mine and mill, mechanical design in copper sulfide and chemical manufacturing. Five years as steel mill metallurgist; 9 months in survey, reports, ore dressing, and mill supervision with chemical manufacturer. $6000. Any location. S(M)-1853.

Nonferrous Metallurgist; Met, age 40. Twelve years in charge of quantity, quality of production, maintenance, safety, and costs with lead smelter. About $650. Any location. S(M)-961.

—POSITIONS OPEN—

Consulting Engineer; metallurgist with wide experience in copper

(Continued on page 646)

A weekly bulletin of engineering positions open is available to AIME members at a subscription rate of $3.50 per quarter or $12 per annum; $4.50 per quarter or $14 per annum for nonmembers, payable in advance. Local offices of the Personnel Service are at 8 W. 40th St., New York 18; 57 Post St., San Francisco; and 29 E. Madison St., Chicago 1.

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PERSONNEL

(*Continued from page 644*)

smelting and refining and familiar with operations and engineering in various copper producing areas of the world. Will provide technical direction for metallurgical plant design and construction, technical assistance to operating smelters and refineries, and operating smelters and refineries. Will also handle development work for new methods. Must be top-notch with broad experience. Some travel. Salary, open. Location: West. W7906.

Sales Engineer in powder metallurgy, preferably with technical and production experience. Sales experience valuable but not necessary. Contacts are in all phases of iron and associated metal powders, and in vacuum metallurgy. Location: Midwest. W7902.

Sales Engineer with three to five years metallurgical development and marketing experience. To plan and execute market research and development, perform application and technical service duties in alloy wire fields. Considerable travel. Salary, $10,000 to $12,000. Company will pay placement fee. Location: Pa. W7884.

Welding Engineer with metallurgy degree and at least seven years experience, preferably in nonferrous metals. Must be acquainted with X-ray techniques, familiar with aircraft or equivalent quality requirements. Will have complete responsibility for technical aspects of welding program, i.e., selection of equipment application techniques, joint design, establishment of procedures, and so on. Salary, open. Location: Pa. W7867.

Sales Engineer, preferably with connections in nonferrous, iron, and steel industries. To act as representative for British company which manufactures ingot casting machinery for the handling of nonferrous and pig iron, also electric arc steel smelting furnaces. Salary, open. Location: East. W7812.

Sales Vice President; metallurgy or mechanical engineering graduate with considerable sales management and sales promotion experience in nonferrous metals and fabricated products. Salary, $35,000, plus bonus. Location: East. W7803.

Metallurgists to promote the use of ferro alloys and metals, and to assist in the development of new products. a) Graduate metallurgist with at least five years experience in the nonferrous field, chiefly in the production and processing of wrought and cast aluminum alloys. Some practical knowledge of other metals, such as copper and titanium, is desirable. b) Metallurgist with good background in steel production, primarily melting and processing of unalloyed and low-alloy open hearth and electric furnace tonnage steels. Should have good experience in the established practices, including application of ferro alloys, refining agents, quality control, and inspection procedures. Salaries, open. Location: Midwest. W7488.

Sales Representative; metallurgical training with some experience in manufacturing or laboratory. To contact industrial furnace manufacturers, alloy fabricators, and various users of high-temperature equipment, such as cement kilns, petroleum refinery furnaces, vitrous enameling plants, heat treating and brazing companies, and others. To sell heat-resistant alloys in wrought form. Salary plus incentive dependent upon experience. Location: Chicago. C7659.

Plant Manager with some technical training to assume responsibility as supervisor of factory operations. Must be experienced in aluminum permanent mold design and operation. For volume aluminum casting product. Salary, $10,000. Employer will pay fee. Location: Ill. C7638.

General Manager; graduate engineer or B.A. with heavy experience in iron, steel, or nonferrous forgings or castings and machining. Should have functional experience as line supervisor in production or metallurgy. Must have at least five years experience as asst. or general manager of an integrated operation or division. Company produces cast iron and nonferrous castings from medium to large sizes. Machine shop is well equipped. Will be responsible for production, metallurgical engineering, sales accounting, and so on. Salary, $25,000 to $30,000 in total, with part of it base salary and the remainder bonus and profit sharing. Employer will pay fee. Location: Ohio. C7639.

Specification Writer with metallurgy degree. Must have five to ten years experience, including firsthand knowledge of engineering society and military standards and specifications systems encountered in procurement, identification, test of materials, and components of standard items in alloys and exotic materials. US citizenship for at least 10 years and be qualified to satisfy class "Q" clearance requirements. For laboratory operation. Salary, $625 to $775. Location: San Francisco East Bay. S(P)-4623-R.

Research Engineer; M.S. MetE, ChemE, or Chem (not Mining), or B.S. with exceptionally strong research experience. Must be interested in applying knowledge to solution of industrial problems rather than to fundamental research. Dept. conducts applied research and development on new processes and

(*Continued on page 652*)

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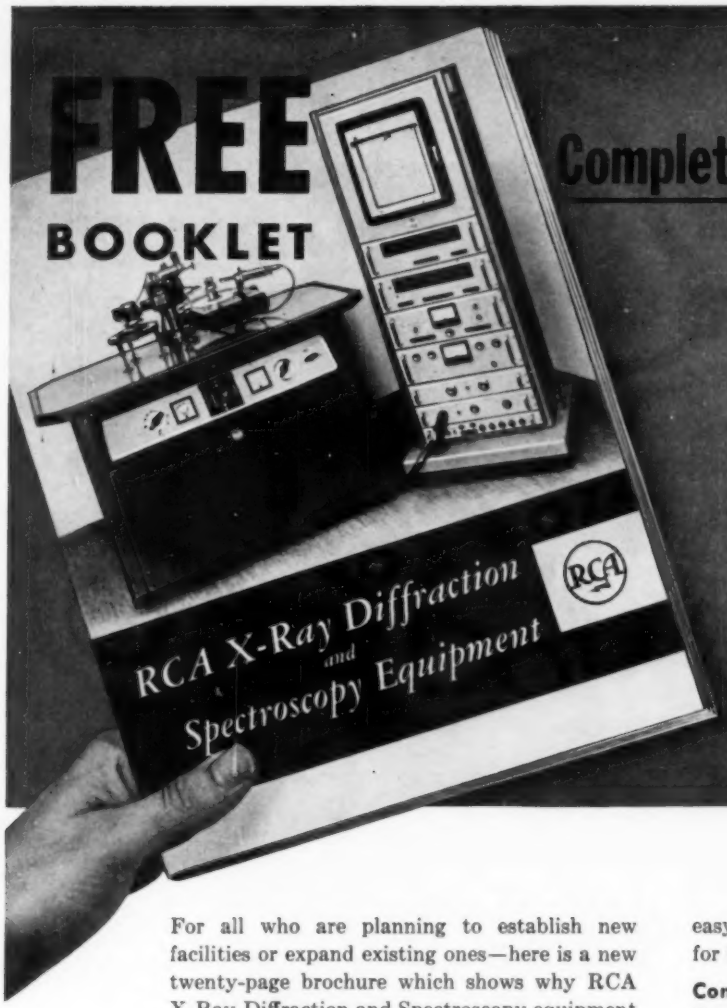

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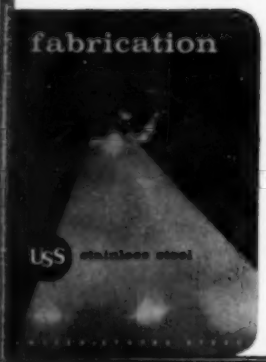

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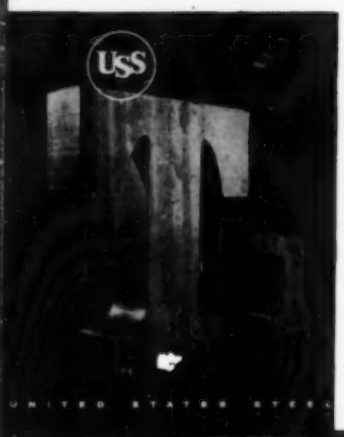

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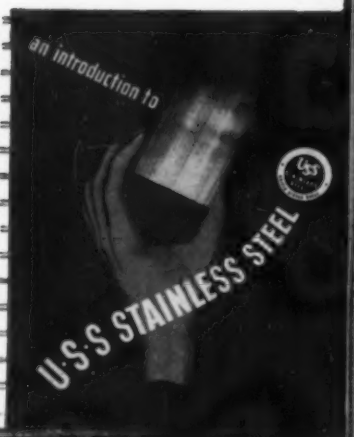

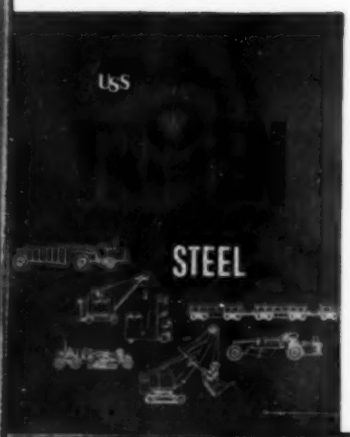

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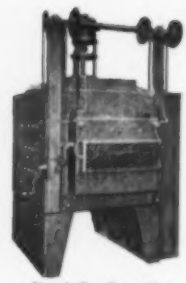
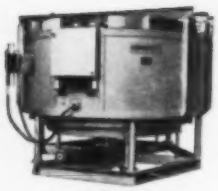


Electric Box Convection Furnace

Tool-Room Furnace with Quench



Electric Rotary Hearth Furnace

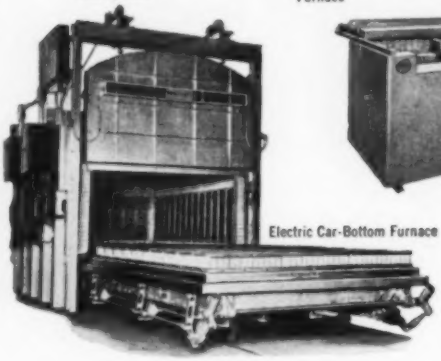
Graphite Resistor Tube Furnace

"Circ-O-Therm" Laboratory Oven

Rotating Tray Oven

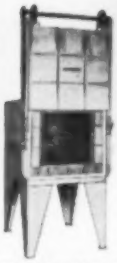
Coke or Ore Testing Furnace

Electric Endothermic Atmosphere Generator



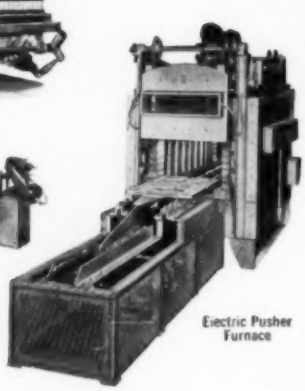
Electric Car-Bottom Furnace

Immersed Electrode Salt Bath Furnace

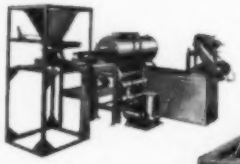


Electric Draw Furnace

Gas-Fired Endothermic Gas Generator

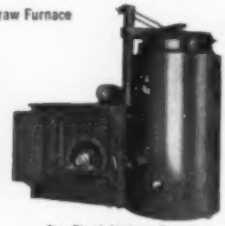


Electric Pusher Furnace



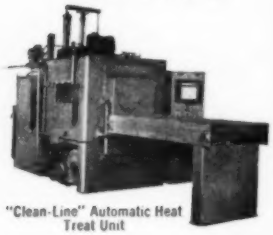
Electric Shaker Hearth Furnace

Gas-Fired Salt Pot Furnace



Gas-Fired Airdraw Furnace

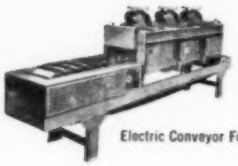
Electric Vertical Retort Furnace



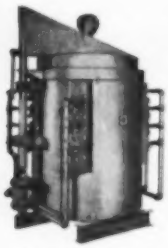
"Clean-Line" Automatic Heat Treat Unit

Laboratory Muffle Furnace

Combustion Tube Furnace



Electric Conveyor Furnace



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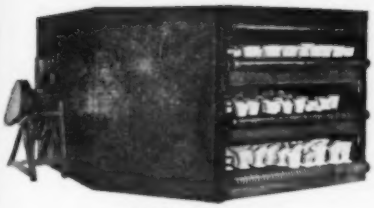
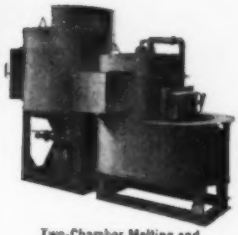
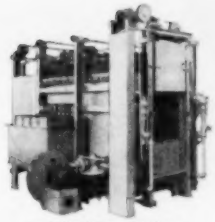


Multi-Level Belt Dryer

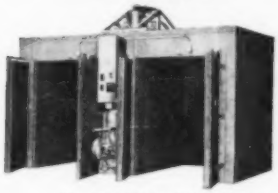
Monorail Conveyor Oven



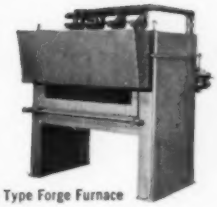
Two-Chamber Melting and Holding Furnace



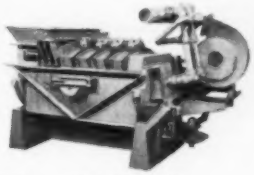
Fuel-Fired Reverberatory Furnace



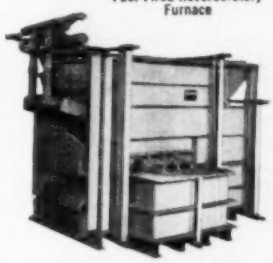
Two-Chamber, Rack-Loaded Oven



Slot Type Forge Furnace

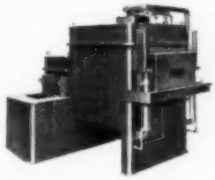


Cradle-Type Melting Furnace



Reverberatory Aluminum Melting Furnace

Gas-Fired Tray Loaded Oven



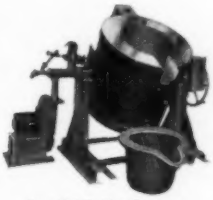
Double Chamber Dry Hearth Melting and Holding Furnace

Magnesium Melting and Holding Furnace

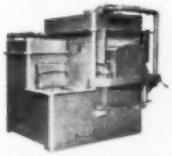
Gas-Fired Barrel Melting Furnace

Electric Resistance Holding Furnace

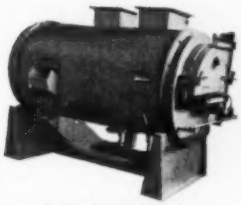
Electric Tray Loaded Oven



Iron Pot Melting Furnace

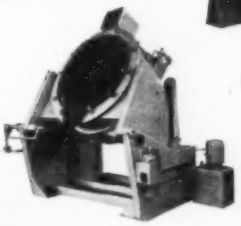


Double Chamber Aluminum Melting and Holding Furnace



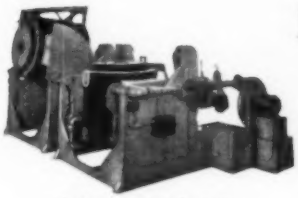
Double Chamber Barrel Furnace

Stationary Crucible Melting Furnace



Hydraulic Tilt Iron Pot Furnace

Electric Crucible Holding Furnace



Mechanically Tilted Crucible Melting Furnace

Gas-Fired Crucible Melting and Holding Furnace

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PERSONNEL

(Continued from page 646)

major process improvements in fields of mineral beneficiation, hydrometallurgy, and pyrometallurgy. Salary, commensurate with training and experience, plus liberal fringe benefits. Location: West. S(P)-4645-R.

Research Metallurgist with B.S. or M.S. Must be qualified to deal with challenging metallography and metallurgical laboratory practices and studies. Prefer a knowledge of powdered metals. Will assist in research and new product development of refractory metallurgy. Should have knowledge of physical chemistry to use advanced equipments, tests, and instrumentation. Should also have an interest in electrolytic process development. For manufacturer's laboratory. Salary, $650 to $750 and up. Location: San Francisco Bay Area. S(P)-4636-R.

Gold Assayer; Met or ME well experienced in gold cyanide milling to be in charge of assay and metallurgical testing to improve mill recovery. For a 16,000-ton-per-month gold quartz ore and amalgamation facility. Sand and slime cyaniding, plus iron and lead flotation. Salary, $6000 and up. Location: S. America. S(P)-4633.

a) **Design Engineers** with Min, Civ, or ME degree preferred. With previous industrial design experience in connection with mining, ore dressing, and smelting or refining plants, equipment and facilities. b) **Construction Engineer** for smelting plant. CE or ME with previous experience in directing or co-ordinating plant construction work, preferably in connection with nonferrous smelting plants. c) **Estimator** with broad experience in heavy industrial construction and engineering estimating, preferably mining and mineral industries. MetE, MinE, or ME. Must be qualified to make cost estimates on projects, budgetary and appropriation estimates, and supervise small group. Salary plus benefits. Location: West. S(P)-4627.

Research Engineers with B.S. or M.S. in MetE or welding and experience in fabrication of ferrous and nonferrous light metals. a) One with special experience in joining problems (welding, brazing, soldering); b) another with special experience in metallurgy of magnesium castings. Work with metallurgical and metal finishing group. Salary, open. Location: Los Angeles county. S(P)-4580-R.

Lead Metallurgist; MetE or ChE. Experienced in or aptitude for lead smelting for development, research, and operation. Salary, $500 or more. Location: Midwest. S(P)-4567-R.

Instrument Designer experienced in the design, selection, and application of recording instruments and automation systems. With nonferrous metal concern, including mill, mine, and smelter. Salary, $640 to $864. Location: N. Mex. S(P)-4535.

Designer qualified to lay out and design machinery, installations, and industrial buildings (mills and smelters). For engineering dept. of operating company. Salary, $539 to $727, depending on man. Location: Southwest. S(P)-4468-R.

Mill Superintendent experienced in gold quartz metallurgy and operation, particularly in cyanidation. Must have a good knowledge of Spanish. Mill has a 20,000-ton-per-month capacity. Ore treated is gold bearing quartz, recovered by amalgamation and cyanidation. A lead concentrate is also recovered by flotation. Need man by Oct. or Nov. to familiarize himself with mill and operation. Salary, about $650. Location: S. America. S(P)-4556.

RESEARCH METALLURGISTS

MATERIALS ENGINEERS

CERAMIC ENGINEERS

SOLID STATE PHYSICISTS

Advanced Technology Laboratories currently can offer a number of senior and junior grade positions in connection with materials research and development programs in the nuclear field.

Opportunities exist for metallurgists, ceramic engineers and solid state physicists to carry out both basic and applied research in connection with fuel element development programs. Materials engineers are needed for several advanced reactor design projects. A number of interesting investigations are currently in progress covering the fields of mechanical metallurgy, alloy development, and ceramic fabrication techniques.

Send resume, in confidence to Dean W. Townsend,

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A DIVISION OF AMERICAN-Standard

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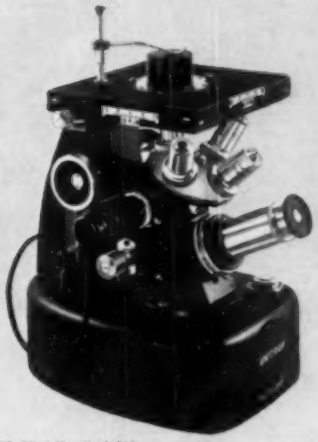
These typical 25 took a total of 152

HERE ARE 25 DISCRIMINATING BUYERS WHOSE OVER 152 ORDERS AND REORDERS PROVE COMPLETE SATISFACTION WITH THESE TWO UNITRON INSTRUMENTS. AMERICAN BRASS, BATTELLE MEMORIAL INSTITUTE, CARNEGIE INSTITUTE, DOW CHEMICAL, E. I. DUPONT, GENERAL ELECTRIC, GENERAL MOTORS, GOODYEAR ATOMIC, I. B. M., MINNEAPOLIS HONEYWELL, M. I. T., MISSOURI SCHOOL OF MINES, MOTOROLA, NATIONAL BUREAU OF STANDARDS, NATIONAL CASH REGISTER, R.C.A., REYNOLDS METALS, UNION CARBIDE & CARBON, UNIV. OF COLORADO, UNIV. OF CINCINNATI, UNIV. OF WASHINGTON, UNIV. OF WISCONSIN, U.S. GOVERNMENT, U.S. STEEL, WESTINGHOUSE ELECTRIC.



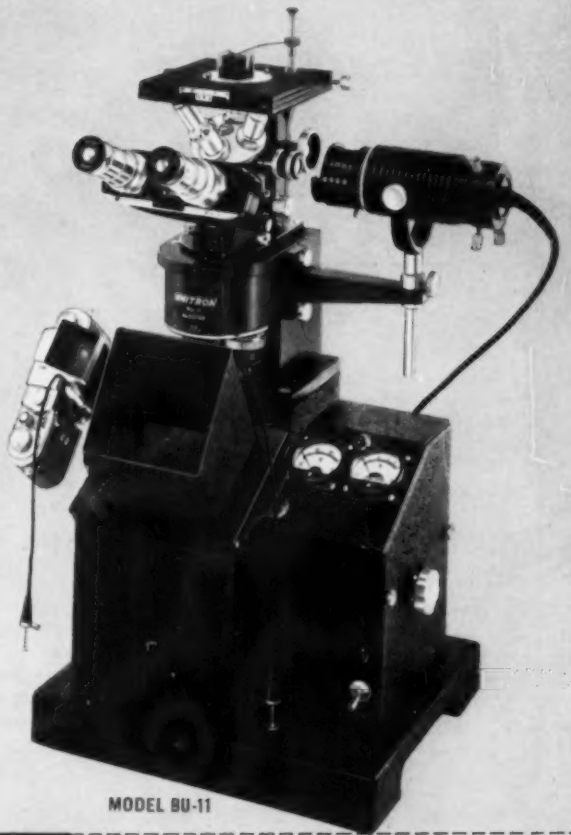
MODEL MEC

UNITRON INVERTED Metallurgical Microscope: This compact unit provides many of the features usually found only in larger metallographs. Standard equipment includes optics for 25–1500X, polarizers, filters, transformer in base, etc. A built-in camera attachment for 35mm. photography is included with the binocular and available for the monocular model. Extra accessories include Polaroid camera attachment, vacuum heating stage and illuminator for transmitted light. Think of the time which your laboratory can save by providing each metallurgist with one of these handy, inexpensive units for use at his desk.

Monocular Model MEC $399 **Binocular Model BMEC $615**

UNITRON METALLOGRAPH and Universal Camera Microscope: A completely self-contained instrument of modern design for visual observation, photography, projection, and measurement of both opaque and transparent specimens; using bright field, dark field, or polarized illumination. Standard equipment includes all optics for 25–2000X, polarizers, filters, 3¼" x 4¼" camera, and many accessories. Also available are camera attachments for Polaroid, 35mm., and motion picture photography; vacuum heating stage for temperatures to 1500° C.; and macro-objectives (5–40X). Even laboratories on a limited budget can enjoy the precision, speed and efficiency possible only with a complete installation of this type.

Monocular Model U-11 $1195 **Binocular Model BU-11 $1379**



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REFRESHER COURSES

► Engineers and managers who return to the campus for refresher courses pay dividends for employers, according to a survey undertaken by Prof. Reno R. Cole, University of California, Los Angeles.

Analyzing results of short courses given at his school, Prof. Cole found that participants made "rapid progress" in their organizations after returning from a refresher course. Some "enjoyed salary increases of more than 50 pct, . . . advanced three to four job levels, and now have 500 to 600 more subordinates than when the course was taken."

Those being groomed for greater responsibility, men in a specialization who incur more general responsibilities than require wider knowledge, and those who have been too busy to keep abreast of developments in engineering and management were found to benefit equally from such course work.

► A history of uranium mining enterprises in the Elliott Lake, Ontario, Canada area (see p. 628 in the September issue) has been captured on film in *A City is Born*, produced for the Ontario Dept. of Mines. The 27-min color, sound film shows how the influx of mining men and construction workers transformed the area almost overnight. The mining operations themselves are treated only incidentally, serving as a backdrop to the growth of the mining community. Available on free loan, the film may be ordered by interested organizations by addressing the Dept. of Mines or the Dept. of Planning and Development, Ontario, Canada.

FELLOWSHIPS

► A doctoral program in metallurgy has just been authorized for the University of Arizona. And its first participants will be three AIME student members. Edward D. Albrecht, Kewanee, Ill., Bruce A. Riggs, Woodland Hills, Calif., and Walter W. Walker, Winslow, Ariz., will receive $2000 fellowships under terms of the National Defense Education Act.

Under the Act, any accredited institution of higher education can apply for a new or expanded program. At the same time, they may request a certain number of graduate fellowships for students to participate in such a program. The dual purpose is to assist educational institutions in establishing doctoral programs while at the same time providing opportunities for students who could otherwise not afford to continue their education.

BOOKS

► More than 100 types of equipment and techniques for the cleaning and preparation of metal surfaces are listed in a handbook published by the Equipment div., Magnus Chemical Co., Inc. The 32 p. booklet describes such methods as degreasing, decarbonizing, washing, bonderizing, stripping, drying, blackening, phosphatizing, rust proofing, pickling, and coating. Copies may be obtained without charge by writing the: *Equipment Division., Magnus Chemical Company, Inc., Dept. J of M, Garwood, N. J.*

► Publication of a technical bulletin outlining the safe handling of sulfur dioxide has been announced by Monsanto Chemical Co.'s Inorganic Chemical div. The bulletin is designed for those engaged in transporting, storing, or using the chemical, and includes sections on containers, unloading, equipment care, and leakage and safety precautions. It also contains a description of the physical properties of liquid sulfur dioxide, including a reference table giving the pressures of tne chemical at given temperatures.

Copies of the bulletin may be obtained free by asking for I-173 from the *Inorganic Chemicals Division, Monsanto Chemical Co., 800 N. Linabergh Blvd., St. Louis 66, Mo.*

UNDERGRAD CONFERENCE

Three AIME student members—Donald C. Brillhart, Illinois Institute of Technology; James J. Rechtien, Purdue University; and Francis A. Shunk, Texas Western College—took part in the fifth annual Summer Conference for Advanced Undergraduate Students in the Dept. of Metallurgical Engineering at Rensselaer Polytechnic Institute.

The objectives of the 20-lecture program were "to stimulate interest in advanced study and research in engineering materials . . . emphasize the growing importance of sciences in the materials field . . . and explore the possibilities of an honors graduate program for exceptionally able students."

Dr. Arthur A. Burr, head of metallurgical engineering at the Institute was in charge of the courses on modern physical chemistry of materials, while Dr. Ernest F. Nippes conducted the courses in modern materials physics.

SALES METALLURGIST

Challenging opportunity to develop sales of heat and corrosion resistant castings produced in new high alloy division. Metallurgical degree and customer contact experience essential. Finest living and recreational advantages.

Send complete resume, including salary requirements, and photo if possible, to

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Additional classified advertising appears on pp. 702, 703, 704, and 706.

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Interesting opportunities in a closely knit Research and Development Laboratory in the following project areas:

1. Research on Beryllium Alloys and Mechanical Analysis of Air Craft and Missile Structural Materials.
2. Fabrication methods development for wrought Beryllium Components.

Prefer metallurgist, physicist or mechanical engineer with graduate studies and/or research experience.

Call EN 1-5400 or send complete resume in confidence to:

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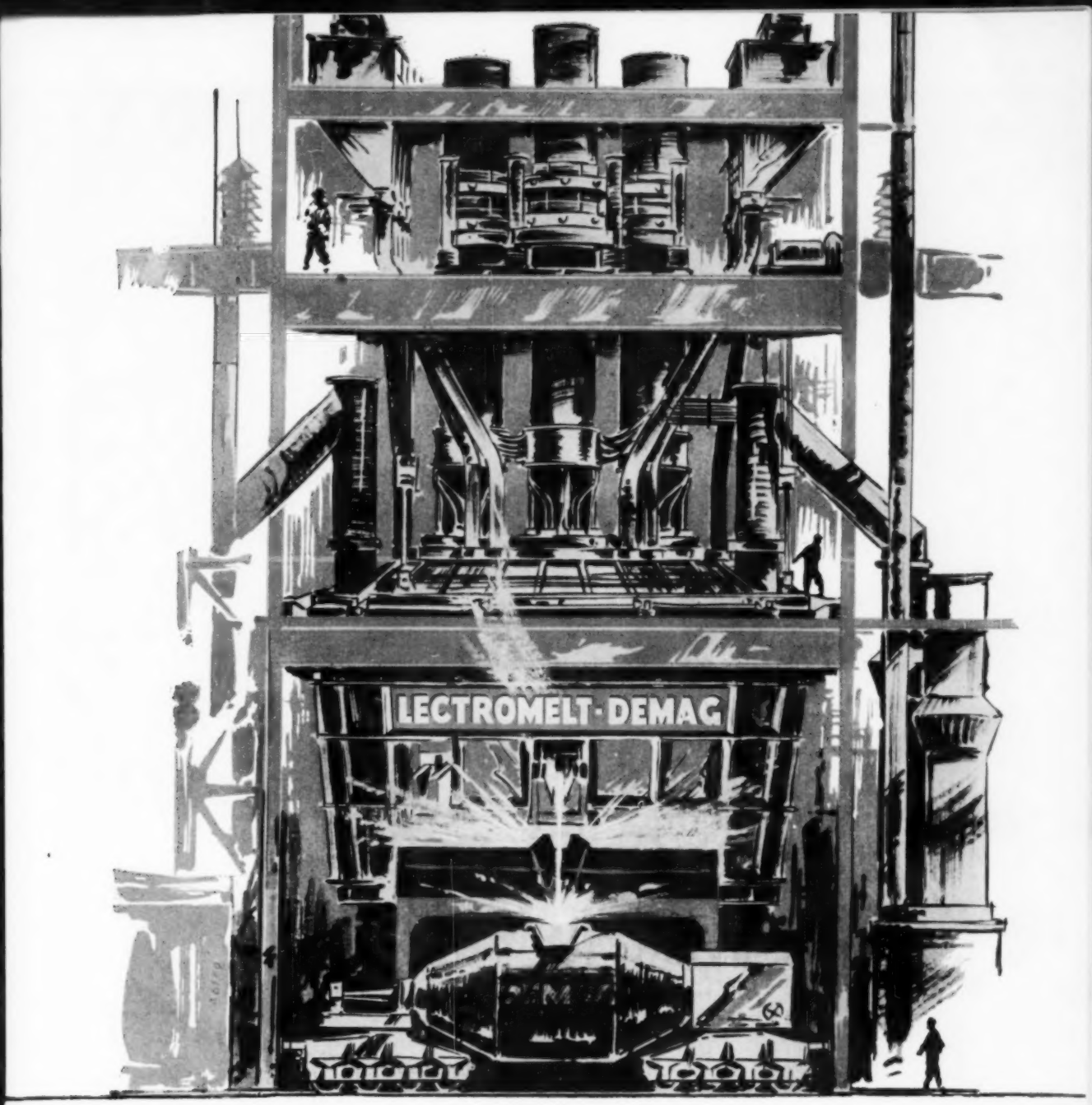
OPENINGS — For Teaching and Research in Solid State and Thermodynamics—Kinetics Areas. Ph.D. Teaching experience desirable but not essential. Salary and academic rank open. Reply to Head, Department of Metallurgical Engineering, Michigan State University, East Lansing, Michigan.



New highs in efficiency, economy and safety with LECTROMELT-DEMAG electric smelting furnaces

The advanced design of the Lectromelt-Demag smelting furnaces assures you of the highest electrical and thermal efficiency. For example, electrical losses in the electrodes are minimized by low-level electrode clamps. Hydraulic compression of contact clamps provides uniform pressure, preventing distortion.

Ease of operation gets similar attention. All operations are planned for handling by semi-skilled operators. Furnace controls are mainly mechanical or automatic, with provision for remote control.

To this efficient Demag design, Lectromelt brings its experience in engineering and quality workmanship. The result is unmatched economy and dependability in all smelting applications.

For help in adapting electric furnaces to your requirements, contact Lectromelt Furnace Division, McGraw-Edison Company, 326 32nd Street, Pittsburgh 30, Pa.

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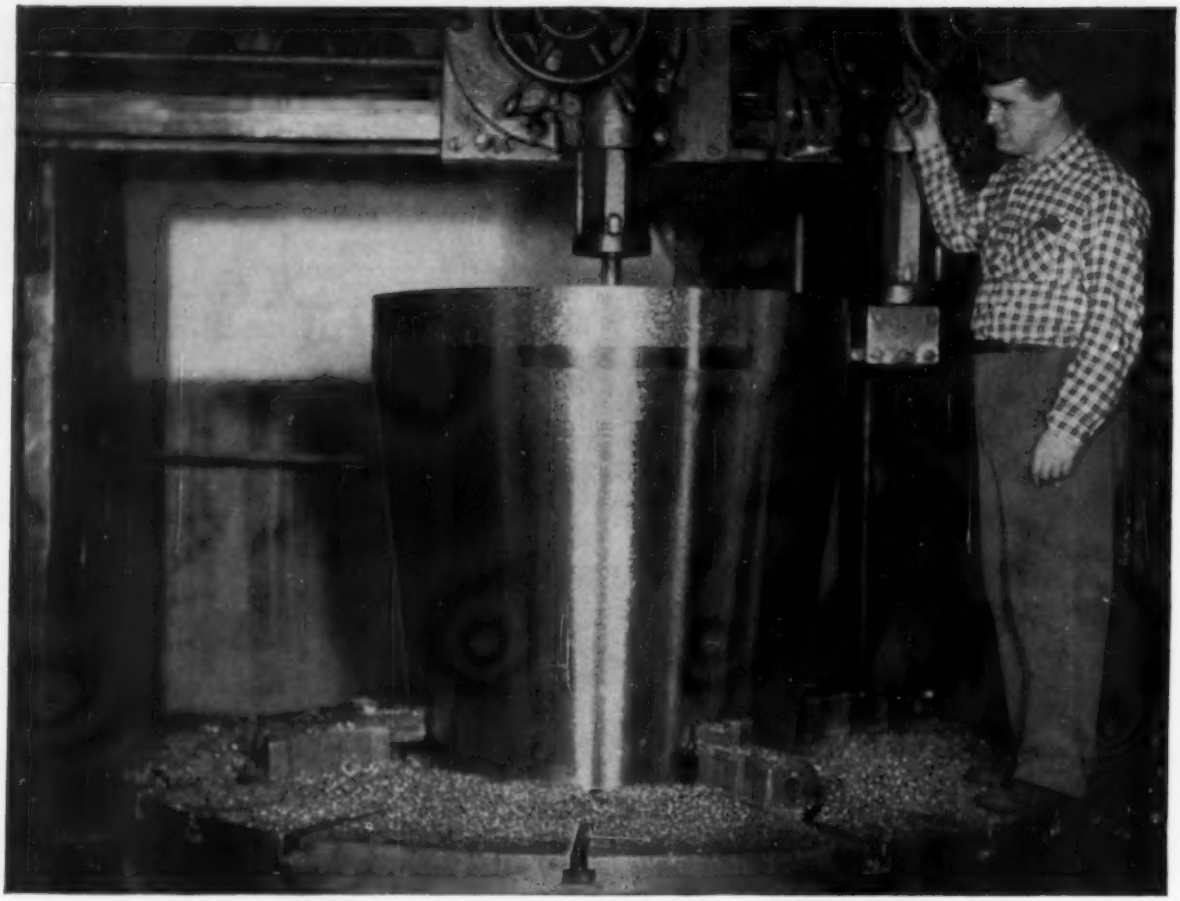

Five times longer service expected from Ni-Vee bronze filter cone. Cast by A. W. Cadman Mfg. Co., Pittsburgh, Pa. Finished and installed in 12" automatic self-cleaning strainer by S. P. Kinney Engineers, Carnegie, Pa.

Cone made of Ni-Vee* bronze to last 5 times longer in acid river water

The filter cone you see above is being readied for work in corrosive Monongahela River water.

That's why it's made of Ni-Vee bronze.

Expected life is at least five times longer than its predecessor, a grey iron cone now badly eaten away. Installed in a 12" automatic self-cleaning strainer, the Ni-Vee bronze cone will give long-lasting support to filter elements that remove solids from water used for blast furnace cooling.

Another important consideration in making this cone was machinability – all outer surfaces were drilled to receive filtering elements. Ni-Vee bronze easily met this need.

Versatile Ni-Vee bronze

Ni-Vee bronze does a multitude of industrial jobs. Five basic bronze compositions are available – Ni-Vee A, B, C, D, and E. They're modifiable to meet all industrial needs for brass and bronze constructional, pressure or bearing castings.

All the Ni-Vee bronzes deliver excellent "as cast" strength, improvable with heat treatment. (For example, Ni-Vee A bronze yield strength can be increased from 22,000 psi as cast, to 55,000 psi!) In addition, they supply easy castability, low shrinkage, pressure tightness, fine grain size and overall economy.

Each Ni-Vee bronze provides special properties. Type A gives extreme strength. Type D furnishes very high resistance to seizure and galling. All types show little dezincification or stress corrosion under corrosive attack.

Informative booklet on Ni-Vee bronzes

"Engineering Properties and Applications of Ni-Vee Bronzes" covers alloy compositions, strength properties, resistance to high temperatures, corrosion, wear, along with other helpful information. Write us for your copy. *Registered trademark

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Chinese estimates revised

Speaking before the National Assembly of China, Chou En-Lai recently announced that the economic plan for 1959 would meet with "a general reduction of its goals." He explained that the goals set for 1959 were excessive, and due to inexperience in planning. Chou said: "It does not fit any longer to equate the production of steel this year with that of the UK. In place of 18 million metric tons, the goal of the plan has been changed to 12 million, or a reduction of 33 pct." At the same time, the Politburo spokesman admitted that 1958 steel production was 8 million metric tons, not 11 million as previously announced. (The March, 1959 issue of JOURNAL OF METALS, p. 183, cited the New China News Agency in saying that its 10.7 million metric ton goal had been exceeded. "Whether or not there has been any confusion between steel and iron production statistics is impossible to say," the article noted, "but the initial 1959 target for steel is 18 million metric tons.")

The announcement also brought forth a failure in the goals of Red China's so-called "back-yard furnaces." The move to produce steel with these low-shaft furnaces has been abandoned permanently.

USBM plans extensive research

Plans for the US Bureau of Mines' 1959-1960 fiscal year pose an extensive research program with a vast array of metals. Following is a sampling of the work to be undertaken:

Columbium and Tantalum: Accelerated columbium-tantalum research will probe low-grade domestic raw materials as sources of the two metals. Kroll-process, bomb-reduction, and fused-salt electrorefining studies will be expanded, and new work begun on preparing columbium by thermal decomposition, using a method similar to the van Arkel-deBoer iodine process. The Bureau is also continuing studies in the physical metallurgy of columbium to determine mechanical properties. (The Hudson-Mohawk section of AIME is planning a symposium on columbium for 1960. See story, p. 702.)

Chromite: Beneficiation studies emphasizing chemical treatment, electric-furnace smelting, and flotation techniques in domestic low-grade chromite-bearing materials is also on the docket. Other work is to include research on recovering chromium from laterites and serpentines by hyro- and pyrometallurgical techniques.

Bauxite, alumina, and aluminum: Economic processes for producing aluminum from low-grade domestic ores is the goal of Bureau of Mines researchers. Several methods for recovering alumina from non-bauxitic raw materials will also be analyzed. Improvement of bauxite recovery in mining will be facilitated by laboratory tests of a strain gage carrier and other instrumentation devices.

Nickel-Cobalt: The difficult task of separating nickel from cobalt will occupy researchers at the Bureau this fiscal year. The preparation of high-purity metals and methods for recovering nickel and cobalt from high-alloy scrap materials will also be undertaken.

Lead and Zinc: The Bureau of Mines lead and zinc program will stress recovery from oxidized ores and sulfide slimes. Various reagents will also be tested, including surfactive organic chemicals. Synthetic organic polyelectrolytes and nonionic flocculents will be tested in connection with flotation and the possible concentration of slimed sulfides in a hydraulic cone.

Mercury: Extracting mercury from domestic ores and concentrates by leaching is the Bureau's goal. In addition to analyzing factors that influence dissolution of cinnabar—mercury's principal ore—metallurgists there will evaluate the use of electro-osmosis for forcing a solvent through rocks. By this they hope to achieve in-place leaching, with concurrent deposition of pure mercury for solution.

Rare-earth metals: Research in electrolytic reduction of rare-earth metals will be redoubled this fiscal year. The Bureau will also try solvent-extraction and ion-exchange techniques in striving for continuous recovery techniques. High-purity cerium and other rare-earth metals with alloy uses will continue to be investigated for physical properties.

Beryllium: Bureau metallurgists will conduct mineral-dressing tests, seeking recovery of beryl by various methods, including flotation. A small experimental flotation plant will be built this year for that purpose. Beryllium concentrates obtained from ore-dressing studies will be reduced to salts and then to metal in bureau laboratories. Bureau of Mines sources indicate that the world production of waste-free beryllium was 7000 tons in 1958. The US produced 463 tons and imported 4599 tons, while 6002 tons were consumed in all.

Titanium made electrolytically

The Norton Co. has developed a system for producing titanium electrolytically which is expected to cut costs. The process is also being used to produce columbium, vanadium, chromium, zirconium, thorium, tungsten, tantalum, hafnium, and molybdenum. Applied to titanium, the electrolytic process uses raw titanium carbide which is about 80 pct Ti.

REPORTER

REPORTER

To smelt mountain top

Nimba, a Liberian mountain, is in for a king-sized head shrinking in order to appease the appetites of the world's iron smelters. Plans are underway to shear off the entire peak—at least 250 million tons of 66.5 pct iron ore. Geologist's estimates make Nimba and the Nimba range from which it comes one of the world's biggest iron ore deposits. Bethlehem Steel Corp. has agreed to contribute an undisclosed percentage of the $200 million needed to finance the project, in return for 25 pct of the profits.

Kennecott revamps smelter

Kennecott Copper Co.'s Utah Copper div. smelter is in for a $10 million improvement and modification program. Western Knapp Engineering Co. will undertake the engineering of the project, which will include conversion of the present pre-roasting process to a direct smelting one . . . modernization of its materials handling system . . . installation of new waste heat boilers . . . and enlargement and modernization of its three reverberatory furnaces. Suspended brick roofs will replace present sprung arch, silica-brick roofs on the furnaces.

Kaiser joins Indian company

Hindustan Aluminium Corp., Ltd., is the offspring of a merger between Kaiser Aluminum & Chemical Corp., and the Birla interests in India. Plans are underway to construct and operate a 20,000-metric-ton aluminum plant at Rihand in Uttar Pradesh province in Central India. Bauxite and alumina byproducts will also be produced.

Cost of the project is estimated at $30 million. Kaiser Aluminum's interest will comprise approximately 27 pct of the company. The Birla group of companies is one of the largest private industrial organizations in India.

Tantalum research grant given

A contract for research and development of tantalum and tantalum-tungsten metal alloys for nozzles and other parts in solid fuel rocket propulsion systems has been awarded National Research Corp. by the US Navy Bureau of Ordnance. The contract is aimed at developing strong, erosion-resistant materials capable of operating at the extreme temperatures existing in the severe environments of solid fuel systems. One promising tantalum-tungsten alloy already tested by National Research exceeds by three times the tensile strength of tantalum at 400°F, and is easily fabricated for production of missile parts.

Develop sulfur-copper alloy

The Bridgeport Brass Co. has developed a new sulfur copper rod alloy which compares to the generally used leaded or tellurium copper rod. The new alloy contains 0.3 pct sulfur. Applications for the new alloy are seen in electrical mechanisms such as switch parts, transistor bases, electronic components, screw machine items, and others.

Magnesium missile metal

Magnesium is under consideration as a missile and space vehicle construction material. According to researchers at the Cryogenic Engineering Laboratory of the National Bureau of Standards, the metal stands up well when subjected to low temperatures, down to —425°F. The six magnesium alloys tested compared favorably, on a strength-to-weight basis, with stainless steel, nickel, and copper alloys.

Krupp-Renn kiln operating

The first of six rotary kilns is operating at the Krupp-Renn plant, Essen-Borbeck, Germany. The kilns are being built by a group of steel concerns. An on-the-spot account will be given in the November JOURNAL OF METALS.

France tries direct reduction

Direct reduction processes are currently on trial at two places in France. *Le Nord Industriel* reports. Forges et Ateliers de Creusot is putting the RN process to work at Miramas (Bouches-du-Rhône). They are accomplishing it with hydrogen from oil refining operations there, it is noted. Meanwhile, the Société Métallurgique de l'Adour is using natural gas from Lacq in its H-Iron tests at the Forges de l'Adour plant at Boucau (Basses-Pyrénées).

Hi-temp metal production upped

Sylvania Electric Products, Inc., has served notice that it will expand production of molybdenum, tungsten, and other refractory metals used in ultra-high temperature applications, such as rockets, jet engines, and industrial furnaces.

A 16-ton isostatic press has been installed at its Chemical and Metallurgical div. headquarters in Towanda, Pa., to produce ingots up to 4 ft 10 in. in diam. A large high-temp sintering furnace is also being installed which will permit production of ingots weighing more than a ton.

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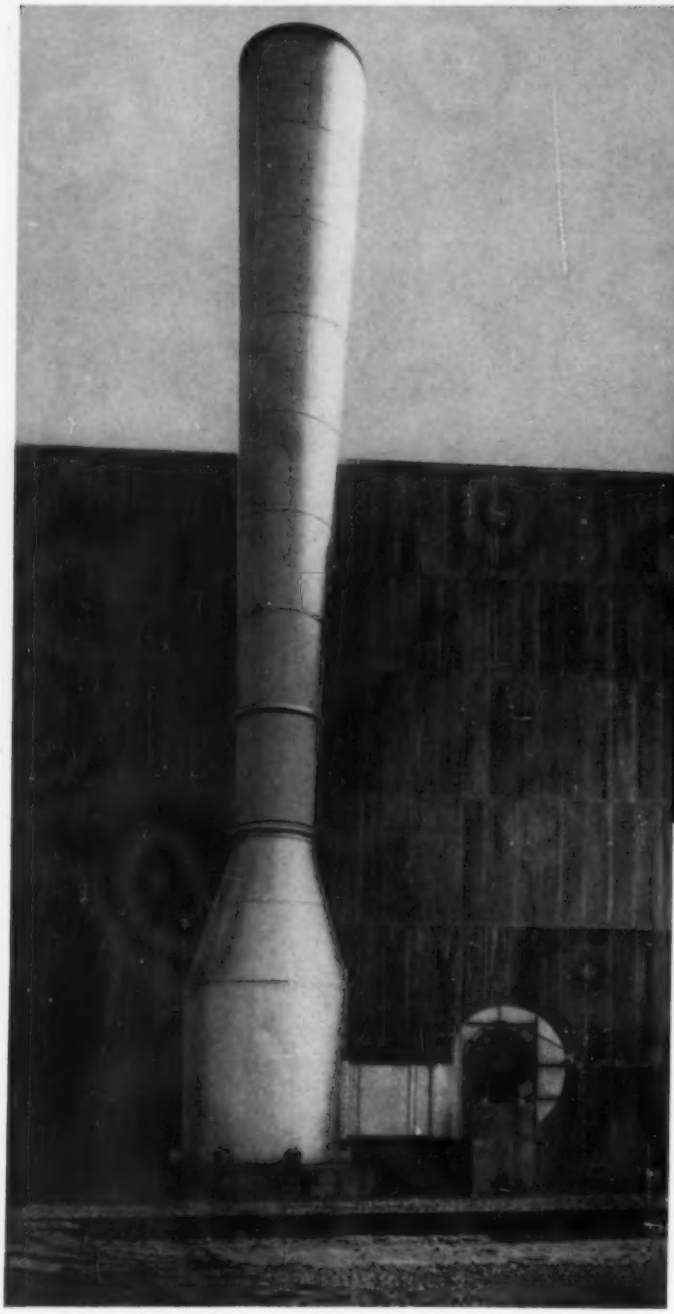

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editorial

After 1965, What?

Throughout the pages of this issue there is a debate going on, and it is indeed a timely one. It centers on metallurgical education in general and materials engineering in particular. Certain industrial groups, you might even say a small but vocal minority, have raised a cry for men knowledgeable in the structure and properties of *all* engineering materials. Their need for such men is real, but the demand for men trained along more traditional lines in metallurgy remains. Thus, this becomes one more pressure exerted upon the school and colleges, one more factor to be taken into account when departments of metallurgy examine their curricula. Our metallurgical schools have always tried to meet the demands of industry—which has never been reticent about expressing its desires. But the pressure has been especially strong in the past ten years, as a large portion of the metals industry has swung from being *producer*-oriented to *consumer*-oriented. In other words, where a product used to be designed within the limitations of the materials available, it is now designed to operate under specified conditions, and industry is assigned the task of coming up with a material that will do the job. What we thought was the tail is now wagging what we thought was the dog.

The argument is a timely one in another sense also, one that affects every member of the Society rather than just college professors and defense contractors. The question is this: Should The Metallurgical Society change to meet this new demand, and if so, how? Other societies are not wasting time in this area—the American Society for Testing Materials is well on the road to founding a Materials Science Division; a group known as the Society of Aircraft Materials and Process Engineers (SAMPE) now has five regional chapters and seems inclined to broaden both its geographical coverage and its present rather narrow scope.

In our long range thinking, should we envision mergers, perhaps one society which covers the production, processing, and science of all engineering materials? Or, considering the drawbacks attendant upon meetings of such colossus societies as ACS, and AAAS, should we direct our thinking toward a larger number of smaller groups, with joint meetings and free exchange of information in areas of overlap? We must consider problems of information storage and retrieval, and the amount of time a research or production man can profitably spend disseminating and gathering technical information, for these problems go to the very heart of any professional society's functions.

It is time for serious, and let us hope prophetic, thought.

J. J. Burke

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ON

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Conducted by

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November 4, 1959
(Fall Meeting of The Metallurgical Society of AIME, Morrison Hotel, Chicago)

Fundamentals of Fission Damage	by J. A. Brinkman
Swelling and Fission Gas Agglomeration in Metal Fuels	by A. T. Churchman
Fundamentals of Inert Gas Agglomeration and Swelling in Metals	by R. S. Barnes
Operational Performance of Bonded and Unbonded Uranium Fuel Rods	by T. T. Claudson, G. T. Geering, J. W. Goffard, and J. E. Minor
Irradiation Behavior of U-FS and U-PU-FS Fast Reactor Fuels	by J. A. Horak and J. H. Kittel
Crystallographic Study of Radiation-Induced Recovery in Cold-Worked Uranium	by D. Tardivon
Irradiation Behavior of UO_2 Fuel Elements	by J. A. L. Robertson, A. S. Bain, G. M. Allison, and W. H. Stevens
The Swelling of UO_2 at High Burnup	by W. K. Barney
Irradiation Testing of Plutonium-Uranium Oxide Nuclear Fuel	by J. L. Bates and W. E. Roake
Irradiation Behavior of ThO_2-UO_2 Fuels	by L. A. Neimark and J. H. Kittel
Release of Fission Products from Fueled Graphite	by W. C. Riley, D. N. Sunderman, and B. W. Dunnington

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Edwin Felch, project director in charge of developing the Titan guidance system, holds the "voice" of the ICBM.

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TRANSACTIONS
OF THE METALLURGICAL SOCIETY OF AIME

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personals

D. A. Rhoades has been named president and chief executive officer of the Kaiser Aluminum & Chemical Corp., subsidiary of Kaiser Industries Corp. With Kaiser for 32 years, Mr. Rhoades was formerly vice president and general mgr of the subsidiary.

John G. McMullin is now supervisor of Structural Alloy Research in the Central Research Laboratory of Crucible Steel Corp. of America. He resigned his position as supervisor of Metallurgy Applied Research, Turbine dept, General Electric Co., Schenectady, N. Y., to accept the post.

C. H. Toensing has joined the Firth Sterling powder metallurgy research staff. Dr. Toensing was previously associated with the Lamp Metals and Components dept, General Electric Co.

Charles R. Funk is now chief metallurgist of the Eastern div. of Colorado Fuel & Iron Corp. Prior to joining CF&I, he was mgr of Metallurgy and Engineering at Alco Products, Inc.

Murray T. Stewart has joined the staff of the International Nickel Co. Research Laboratory at Bayonne, N. J. There he is a member of the Special High Temperature Alloys Section.

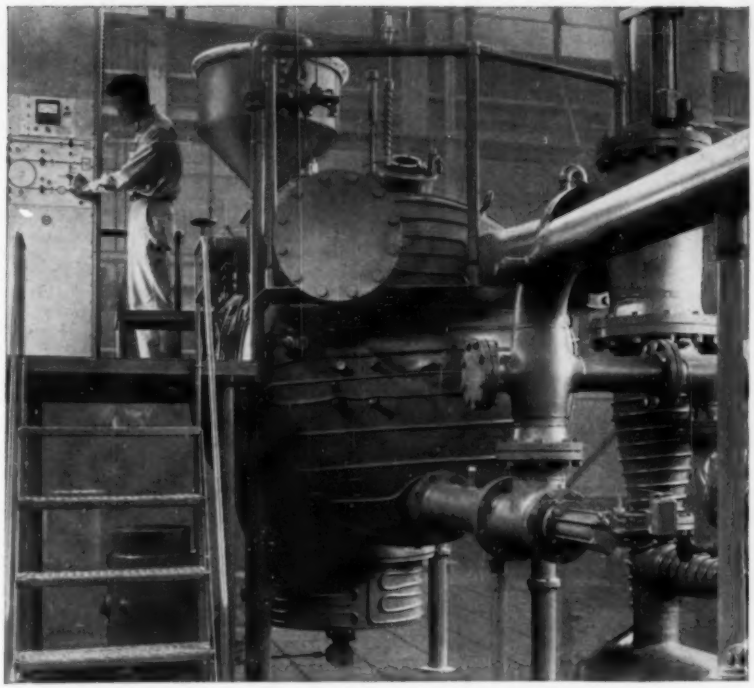
Rolf Nordheim is now the senior research engineer in the Process Metallurgy section of Jones & Laughlin Steel Corp. Dr. Nordheim was formerly supv of physical metallurgy at the Norwegian Defense Research Establishment. Co-author of many papers on high temperature alloy development, he is also a former president of the Norwegian Metallurgical Society.

Giuseppe Testero, director of research, A.F.L. Falk, Sesto S. Giovanni, Italy, has been elected secretary of the Associazione Italiana di Metallurgia.

Richard J. Quigg recently received his Ph.D. from Case Institute of Technology. He is now employed as a research metallurgist for Thompson Ramo Wooldridge, Inc., Cleveland.

S. L. Jackson has been named asst mgr of the Eastern sales region of Union Carbide Metals Co., div of Union Carbide Corp. Before his new appointment, he was mgr of the New York district.

T. P. Colclough of the British Iron & Steel Federation, was recently awarded his Ph.D. in metallurgy from Sheffield University.



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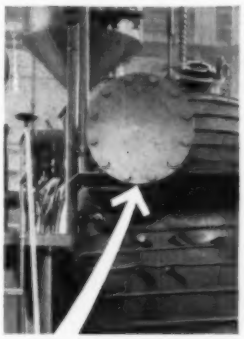

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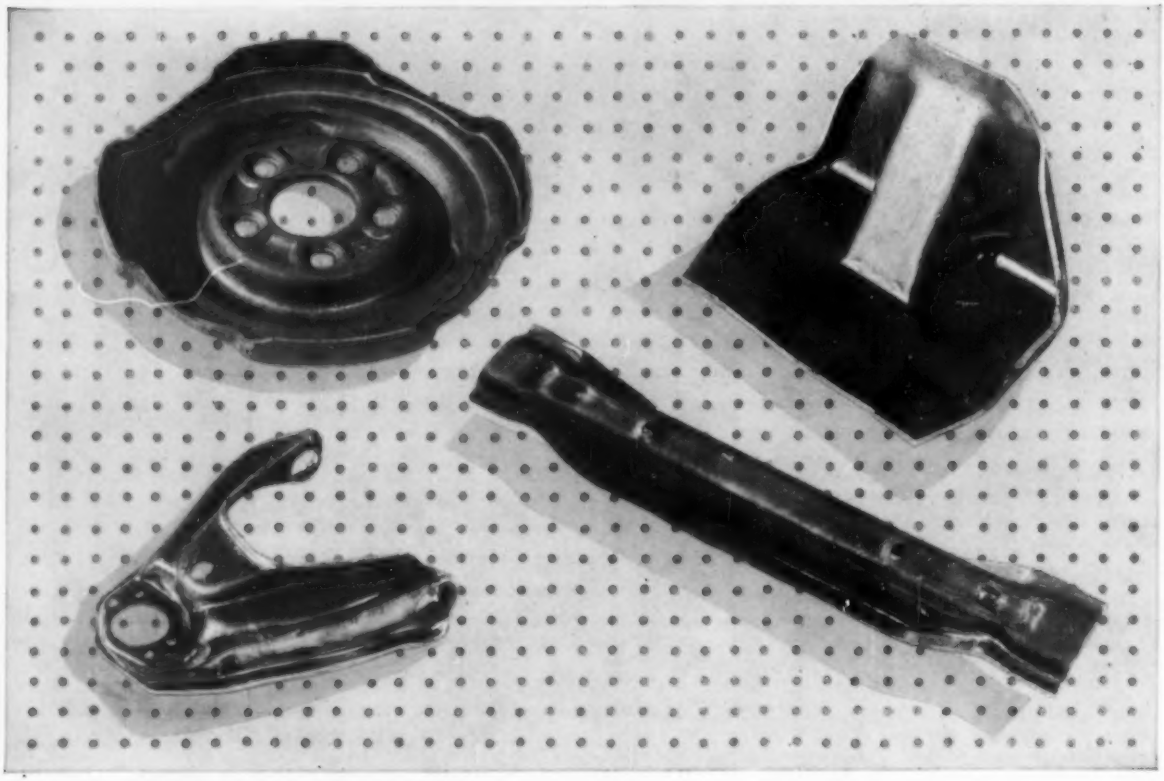

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TOMORROW'S MATERIALS

A distinguished metallurgist looks to the present work in physics and physical chemistry to predict the materials that materials researchers will turn out in the near future.

by W. R. Hibbard, Jr.

TODAY, most of the important new systems and devices in the field of technology depend upon the use of new and unusual materials in critical functions. Travel in space, new sources of energy and energy conversion, and new techniques for the computation and storage of information are three important examples. Accomplishment of each of these tasks depends upon materials not available today, but today's science will lead to these new materials required for tommorrow.

In order to understand the situation fully, we should trace some of the historical aspects of the science of materials. Examination of the literature reveals that yesterday's science of materials was primarily dominated by the producer. Materials made available through the producer's efforts were more than adequate to meet the existing need. More recently, and particularly during the past few years, the consumer, especially the government and its agencies, has been faced with the situation wherein commercial materials will no longer adequately meet all the needs created by new technological advances. As a result, there has been a gradual swing from a producer-dominated to a consumer-dominated science of materials.

Shift in material demand

This point is well illustrated by sampling the literature at ten-year intervals for the last forty years in the fields of metals, ceramics, solid state physics and physical chemistry. Tables of contents of the following journals were analyzed: 1) the TRANSACTIONS of the Institute of Metals Div. and the Metallurgical Society of AIME, 2) the Solid State Physics Sessions of the American Institute of Physics, 3) the Journal of the American Ceramic Society, and 4) the Journal of Physical Chemistry. The analyses were made for the years 1918, 1928, 1938, 1948 and 1958.

Contents of papers from these sources were categorized into 1) basic science—investigation with no apparent commercial application, but aimed at understanding basic or fundamental phenomena; 2) applied science—where basic or fundamental studies of known materials and processes could have commercial value and; 3) development aimed at improving existing materials and processes. In addition, there is another division, related to the type of material; for example, unusual elements such as titanium, zirconium, columbium, and rhenium, which are less available and more expensive than the standard producer materials, such as steel and copper.

Fig. 1 represents a survey of the metallurgical literature taken from the Institute of Metals Division and illustrates the progress over this 40-year period. A trend toward relatively fewer development papers aimed at improving the properties of existing materials and, simultaneously, an increase in a number of papers concerned with basic science is

W. R. HIBBARD, JR., is manager, alloy studies, General Electric Research Laboratory, Schenectady, New York. This paper was given originally at the conference entitled, "The Undiscovered Earth," sponsored by the Southern Research Institute, Birmingham, Ala. Proceedings of the conference are available from that organization.

EDITOR'S NOTE

Throughout the pages of this month's issue are pictures of the actual buildings where metallurgy is taught at various colleges and universities across the nation. We could not get them all in, but we think that a representative sample is pictured, and we hope that your school is among them.

obvious. In addition, Fig. 2 illustrates the appearance and subsequent increase in the number of papers concerned with exotic metals, and finally in 1958 a significant number of papers in the metallurgical literature were concerned with non-metals. In particular, this trend represents a swing from convergent research with material-oriented papers concerning such things as the properties of steel or the properties of copper, toward devergent research leading to phenomena-oriented papers concerned with such things as fracture, deformation, the science of strengthening metals, and the kinetics of the reactions which occur in metals.

Consumers push basic research

The trend to basic research appears to be the result of consumer requirements. In 1948, there was a substantial amount of government sponsored research in the universities, and this continued to expand in 1958, both in the universities and in industry. Also, an expanding amount of industrial research was carried out in consumer industry laboratories in 1948 and 1958. Finally, there is an increasing amount of industry sponsored research in university laboratories. In short, this represents a growing amount of consumer-oriented research with a basic approach stimulated by the government and by industry. The stimulation is derived through a new emphasis of consumer devices that replaces, in part, the stimulation from materials properties and processing. The government, through its various agencies, has contracted with the universities as its source of basic research, and the consumer industries have established their own basic research laboratories.

As in the past, the basic science leading to the solution of the materials problems derives its stimulation primarily from scientific opportunity. This scientific opportunity has as its source a desire to understand the behavior and the phenomena associated with materials, and stems from the fundamental sciences of solid state physics and physical chemistry. On the other hand, this scientific opportunity may result from the material needs of our rapidly moving modern society.

Sources of metallurgical research

We may return to our literature studies to analyze the sources of scientific opportunity coming from a desire to learn and understand. In Fig. 3, there are three vertical columns, the left one representing the solid state physics literature, the center one representing the metallurgical literature, and the right one representing the physical chemical literature. For each of the years indicated, there are listed several pertinent scientific topics that were found in the literature for that year.

By looking down these columns, one may deduce that the atomic structure work appearing in the metallurgical literature in 1928 has as its source a scientific opportunity stemming from the atomic structure work appearing in physics literature previously. Similarly, in 1928 the work on phase diagrams appearing in the metallurgical literature probably stemmed from work in physical chemistry in the same subject in prior years. As we pass down through the years, we find that the work on semiconductors appeared in the solid state literature in 1938 and in the metallurgical literature between 1948 and 1958. Work on dislocations appeared in the solid state physics literature in 1948 and subsequently in the metallurgical literature. The work on oxidation and gas-metal reactions appeared in the physical chemical literature as a forerunner to the metallurgical literature. Thus, the metallurgist has been able to look to the scientific disciplines of physics and chemistry for stimulation and for understanding that could be applied to the solution of scientific problems in his field.

Tomorrow's scientific advances

To follow this extrapolation to the present and into the future, one may look at the physics and chemical literature of today to find important and exciting scientific areas which may lead to the solution of our materials problems of tomorrow. In the physics literature of today, we find a great deal of scientific activity concerned with electronic behavior, the very important phenomena associated with conduction. We also find important scientific activity associated with nuclear behavior, defect structures, and surfaces. These subjects, of course, are related to radiation damage, to surface phenomena such as oxidation and corrosion, and to tiny bits of matter such as *whiskers* with large surface-to-volume ratio. If we look to the current physical chemical literature, we find activity on subjects such as the physical chemistry of very high temperatures, which is, of course, related to the important high temperature containment problem. We also find activity in the field of very high purity materials, which will be related to understanding special materials properties.

It is obvious that scientific opportunity in these areas may also be related to the material needs of society in a rapidly advancing technological age. There are many important areas in which advance is limited by materials. For example, the rocket and satellite field is looking to materials research for the solution to problems of thermal protection and high temperature electronic devices for instrumentation and control. High temperature fuel elements are important to fission. The important computer and information storage developments need microminiaturization, i.e., materials that can be utilized in very small devices. There is also the important area of energy sources and energy conversion. The development of fusion, for example, faces a containment problem. The application of thermoelectric power depends very strongly on our ability to develop new thermoelectric materials with a high efficiency. Utilization of magnetohydrodynamic power is limited by materials for containment of very high temperatures. Tomorrow's materials will meet all of these challenges—through a firm foundation in today's basic research.

Basic research can only be stimulated by scientific opportunity, and not simply by the assignment of problems under the pressure of crash programs. The technological pressure technique is largely used by the Russians, but one cannot produce the scientific advancement to solve these problems simply by turning the faucet on the dollar supply line, although money is essential to all research. One must gather together outstanding scientists with a mission to do fundamental work under the stimulus of scientific opportunity. They must work in scientific areas related to these vital materials problems and they must possess a mechanism for recognizing the solution to these problems as they develop from the scientific efforts. Certainly such arrangements,

(Continued on page 670)

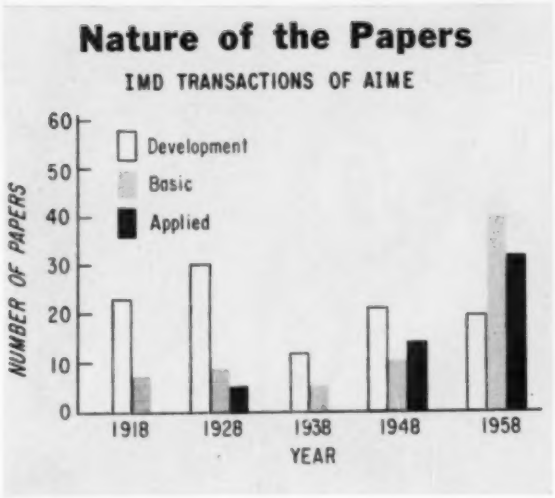


Fig. 1

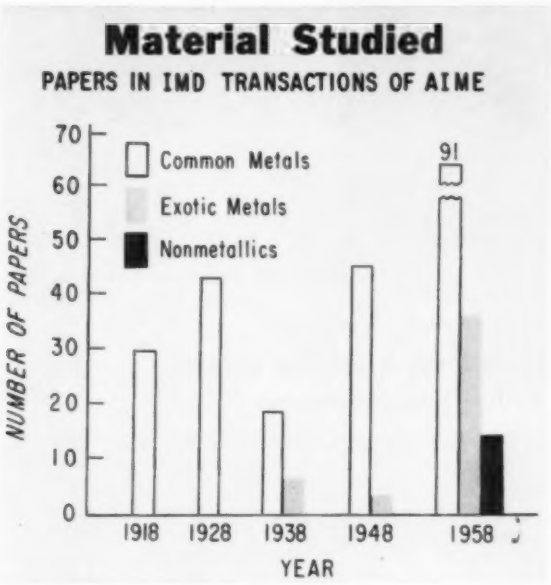


Fig. 2

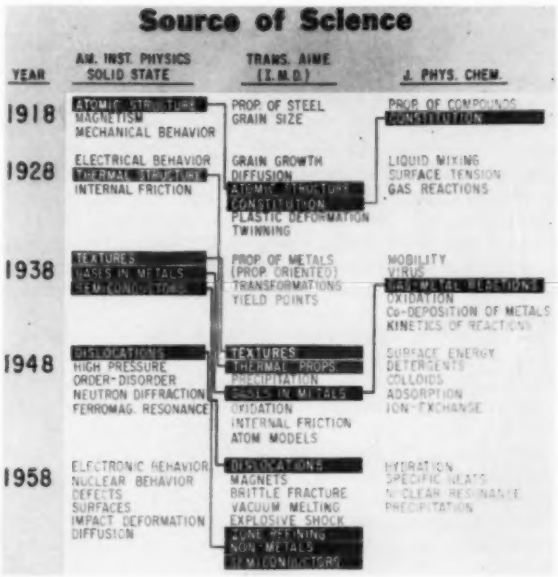


Fig. 3

Hearst Memorial Mining Building, University of California, Berkeley.

in the long run, will lead to the rapid and effective solution of those problems requiring new materials for tomorrow.

The metallurgist as materials engineer

The metallurgist was probably the first materials man to recognize the importance of solid state physics and physical chemistry to his science. From the turn of the century, metallurgy has been performed by people trained and inspired by the physics and physical chemical field. Very early, these people recognized the importance of atomic and crystallographic phenomena. On the other hand, if one looks through the ceramic literature, for example, he will find that in the 1920's and 1930's the ceramists were concerned with natural polyphase materials usually bonded with glasses or clays. The science supporting the development of these materials was primarily limited to phase diagrams, which were rather extensively developed and elegantly utilized. The important properties were controlled primarily by the melting temperatures. Discontinuously in the 1950's, under the stimulation of consumer device requirements, a whole new class of ceramic materials appeared, namely the single phase, polycrystalline, essentially pure chemical compounds, such as ferrites, oxides, and titanates. The impact of these new materials was to change the whole meaning of the term *ceramic*.

Thus, the ceramist joined forces with the metallurgist and his experiences in the chemistry and physics of structures to attack the new problems associated with structure-sensitive properties. As a result, in the 1950's the ceramist looked intensively at the phenomena relating structure to behavior that the metallurgist utilized as early as 1928. Thus, one can use metallurgy as a prototype illustrating the sort of advances which will occur very, very rapidly in the ceramics field in the future. In fact, many of the people working in this field today were trained in disciplines of physics, chemistry, and metallurgy.

Metallurgy is applied physics and physical chemistry

At a symposium on the Structure and Behavior of Matter last Fall, there were representatives from several materials fields: polymers, concrete, wood products, adhesives, ceramics, electronic solids, and metals. After considerable discussion of the scientific problems that are limiting these fields today and the materials problems that must depend upon scientific advancement for their solution, it was agreed that the metallurgist was a pioneer in the application of physics and physical chemistry to the solution of materials problems, and that the other disciplines were just beginning to utilize these approaches. A good example is Professor Herman Mark, who is working in the field of polymers at Brooklyn Polytechnic Institute now. Back in the 1920's, he was doing research on metals using the same approaches that he is using on polymers today. Thus, we can look at the rather slow development over the past 40 years in the field of metallurgy as an example of the type of developments that will occur very rapidly in the next five to ten years in the fields of polymers, concrete, adhesives, wood products, and ceramics; and the important sciences of physics and physical chemistry today will lead to new and exciting materials in all of these fields tomorrow. These materials will result from scientific opportunity and from an awareness of the vital materials problems stemming from the needs of today's society in its technological competition. It is important that we all appreciate the need for this science, support it whole heartedly, and be willing and ready to use it.

Massachusetts Institute of Technology, Cambridge.

Science and Engineering Building, Carnegie Institute of Technology; home of the Metals Research Laboratory.

Materials engineering
Metallurgical education

ORTHODOXY, HETERODOXY, AND METALLURGICAL EDUCATION

A distinguished metallurgist and educator discusses the old and the new in metallurgical education, and suggests a course of moderation to be followed.

by Robert F. Mehl

MOST discussions of metallurgical education deal with ways and means by which certain objectives may be attained, usually relating to rather specific details—organization of courses, course content, instructive experiments, introduction of recent findings of research, minor courses in related fields, and so forth. Although some reference to matters such as these must necessarily be made, the main purpose of these remarks is to examine the status of metallurgical education as it is today, and as it may become in the forseeable future. This is a timely subject, particularly in view of the somewhat fanciful and even immoderate ideas abroad today which concern the whole field of engineering education, and which are beginning to affect metallurgical education.

The word *orthodoxy* in the title means metallurgical education as it used to be, and to some extent still exists in some places; the word *heterodoxy* is intended to represent the most extreme of the new ideas. We must find our best position between these two extremes, neither comfortably, lazily, resting in the old orthodoxy, nor in a state of excitement accepting every new idea without full thought. Both extremes are damned with irresponsibility. The old orthodoxy, as represented by what metallurgical education was, say, some 25 years ago, is now almost gone, and the type of metallurgical education we have now in the best schools may be taken by some as representing a new orthodoxy that needs some touch of heterodoxy to progress. The difficulty is in the word *touch*—how far should one go along wholly new paths? The famous slogan appeals to all of us, that "the heterodoxy of today becomes the orthodoxy of tomorrow,"—but like most slogans, all of them dangerous, it invites careless ideas of progress and needed action. My theme, then, is how can current successful orthodoxy, which could be characterized as *conventional wisdom*, to use Galbraith's phrase, escape, as time goes on, the blight of a too-viscous earthly adherence to what we now think and do, however successfully—without breaking all bonds, flying unguided into the thin clouds of educational fancy.

ROBERT F. MEHL is dean of graduate studies and professor of metallurgical engineering, Carnegie Institute of Technology, Pittsburgh. This paper has been abstracted from a talk presented at the AIME Annual Meeting, San Francisco, February, 1959.

Boundary conditions

In searching out a rationale for undergraduate teaching, it is of first importance to observe that the problem is subject to several boundary conditions that are quite clear. If we do not observe them, we shall go astray. The educational analytical problem will vary from school to school, most particularly from the large school to the small school: from schools that try to serve the metallurgical profession at large (and these constitute the larger and well-known schools) to schools that set very limited objectives—schools that minister to specific industries, or afford training in preparation for graduate work only, to take two examples.

Here, we will consider only those schools that take the whole of the profession of metallurgical engineering as their field of endeavor.

The boundary conditions mentioned above are of extreme importance. If we can define these boundary conditions successfully, the problem of striking a proper educational attitude should be easier, and we may indeed in this manner largely describe what the nature of undergraduate education should be.

The first of these boundary conditions is this: that about seven-eights of all graduates do no advanced study, or so little that this is relatively unimportant in the argument. An educational institution certainly must provide a suitable curriculum for such students. Such graduates procure jobs in industry, they become in large part operators and in time managers in industry, and the needs in training are defined and fixed by this circumstance. No educator determines the needs of the student in the job he will take; though the educator must possess the gift of foresight so that he may provide training for industry as it shall be in a reasonably foreseeable future rather than as it is today—students do live longer than their professors, and have that superb prospect—a long future! The professor himself can

not determine that future through his own special professional interest in his subject. To take a single example, if a professor, through an overwhelming interest in nuclear metallurgy, believes that a course in that subject should be required of all students, he does so at his peril—and that of his students. Analysis of large companies has shown that only 1 or 2 pct of all metallurgical graduates at the bachelor's level are engaged in this subject. This example could be multiplied by many others, all of very minor importance in the general problem of curriculum-forming. The kinds of jobs graduates take spread over an unbelievably wide spectrum—over every aspect of the metal-producing and metal-using industries. The school does not direct this result—industry and the student determine it. It is a fixed boundary condition, and the educator has no choice but to observe it. Nor should a particularly vocal segment of industry be taken as representative of the spectrum of employment. Any given employer might wish for men more narrowly specialized in his own particular field of activity—and he might not be entirely wise in this wish—but the educator must, like the politician, play off one pressure group against another and hope to find the best balance for the population.

This boundary condition imposes fixed limits on the result obtained. First, a graduate at the bachelor's level can only be trained to become an intern in whatever metallurgical industry he elects upon graduation. This is partially due to the limitations of time but much more importantly to the fact that there is so very much to learn of a practical nature, relating to the operation of very large installations of equipment.

These remarks apply to our own country, and are determined by the nature of our country, by its history and by the social, economic, and even political practices that circumscribe and condition it. Other countries have different practices. In many, a college graduate is expected to be made fully ready to take charge of industrial operations—such is the case in Swedish schools, in Aachen, Germany, and to some extent in the Latin American countries. In others the training given is so theoretical and scientific that the graduate is far indeed from a practicing engineer or even an embryonic engineer.

So the boundary conditions we need to speak about are those that pertain to this country, a country in which college education and the training in industry that goes with internship are well adjusted one to the other, as deemed best by the employers of men at the bachelor's level. It is mandatory that educators in this country follow this policy. A radical departure from it will introduce a randomness the result of which is hard to foresee, though surely not in any way promising. Heterodoxy in this respect can be a chimera, seeming to offer more than it in fact can supply, and it can be wholly disruptive, whatever the revolutionary might ambitiously and abortively hope.

Science vs engineering

Now as to the second boundary condition: metallurgical engineering must indeed be a mixture of science and engineering. The word "science" not only means the science given to metallurgical students by science departments (and of course this is of great importance) but also that large body of metallurgical science developed by metallurgical research scientists—what we know about the structure of alloys, about what happens when cold-worked metals are heated, about TTT-curves, and dozens of other subjects never presented to students by science departments. And basic science—the theory of solutions, elasticity theory, chemical equilibria, to take a few examples—is constantly bred into the substance of metallurgical courses. In most of the types of colleges under discussion engineering is added. For example, the preparation, treatment and use of alloys (which is surely engineering), the operation of processes which produce metals and alloys from ores, the forming of metals, the selection, adaptation, and costing of materials and processing—to which one should add minor courses in related engineering subjects.

Certainly this is not to say that such metallurgical courses need be descriptive—this is the old orthodoxy. In metallurgy we have long passed this position, and did so, at least in some schools, about 25 years ago. Descriptive courses—what a blast furnace is and how it is operated, with little or often no attention to the physical chemistry of what occurs in the blast furnaces or to the dynamics of gas flow, to what a given welding technique is and accomplishes (and one could go on with many other examples), are poor education, for the technology of today is history only in the tomorrow. The way in which new science and new engineering principles have for so long been introduced into our curriculum remains an effective way; outmoded or qualitative concepts are replaced by the new and the quantitative, the best that the state of knowledge allows, and, with an active faculty, this is a continuous process, with the most essential principles of the broadest applicability retained.

But courses in basic science alone, as preparation for working in a mill, are nearly as bad, and the employer would find such education quite unacceptable, for there is much to the job of being a mill metallurgist that does not derive directly from the so-called basic sciences. There is much of true engineering. It is sometimes said that engineering is but applied science, and that training for the engineers need only be in science—this is a heterodoxy, though certainly not a new one. Those who take this attitude, and there are some newcomers in this long-continued argument, are inclined to broaden the base for college training in the sciences to include chapters in science only vaguely related to the main task of the metallurgist. A pure scientist enters practical metallurgical work with little confidence, with a feeling of insufficiency, of not-belonging, that takes him years to overcome, if indeed he ever does. Unfortunately, many of those most vocal in argument are research men too enamored with research to be able to view the problem of the student who will stop his training at the B.S. level. We should agree that metallurgy for such men—as contrasted to those engaged in research—is science, engineering, ingenuity, and inventiveness, plus an integration of all these with management and commerce.

Pedagogical approach

Apart from courses in basic science (conventionally taken in the first two years) the present approach to the pedagogy of metallurgical engineering in the best schools is to base all courses on principles of engineering and science—of metallurgical, physical, mechanical, and chemical science—with cur-

rent shop and mill practices used as illustrative material. This is surely not a descriptive approach, it meets the requirements for the B.S. degree very adequately, and (apart from the continued effort to introduce new engineering and science, as research produces it) with the constant revision of individual courses and the whole of the curriculum. All of this relates to the second chief boundary condition: a proper undergraduate curriculum is a compound of science and engineering.

There is a third boundary condition, at least a sort of boundary condition, that derives from the first two. It is this: undergraduates *must* be trained in both extractive and physical metallurgy. It is a solid fact that the undergraduate does not know what type of job he will be offered or will take. It may be in extractive or physical metallurgy; it may be in ferrous or nonferrous metallurgy. Long experience in studying placement records demonstrates this indecisiveness most eloquently. Does it not follow, that ferrous and nonferrous metallurgy, and extractive and physical metallurgy should all be included in the curriculum, partly for the reason stated, but also because these subjects are all related and in many ways dependent upon one another? One can hardly understand the physical metallurgy of steels, for example, unless the full history of the heat of steel concerned, at present beyond the reach of analysis, is known. In practice, a metallurgist working in one field profits immensely by a knowledge of one or more other fields. A properly designed curriculum should—and must—provide training in all of these several branches, and indeed such a curriculum is not only quite possible but has been successful in many places. If basic principles are taught, with examples from practice as illustrations, the schemes may readily be made to work, and the product is a metallurgical engineer.

There is such a thing as metallurgical engineering, or metallurgy, if you wish, despite offhand and captious remarks of those who are so deeply smitten by of their own special interests as to believe them all-encompassing. Metallurgy, in its composite and related whole, is a discipline of its own. Although it draws from other disciplines in both science and engineering, we should not and must not let this confuse us, for all other branches of engineering do exactly the same, and this is most easy to demonstrate. There is something lacking in the public and even the professional reputation of the metallurgist, and some of the uneasiness felt about metallurgical education probably stems from this.

These then are the chief boundary conditions that must be observed in devising an undergraduate curriculum for the great majority of students for whom the B.S. is the terminal degree.

Graduate study

Of course, a provision must be made for those students who have the capacity to go on to graduate work. A simple answer to this problem is, perhaps obviously, an honors system. Such a system provides for replacing certain undergraduate courses—chiefly those that point directly at engineering rather than at science, including minors in electrical and mechanical engineering—by courses that give such students a head start in graduate work. Such an honors program should be an essential part of undergraduate planning, so that the savings in time made can be devoted to either advanced courses in scientific metallurgy or advanced courses in chemistry, physics, and mathematics, particularly the latter. However, the current pattern of undergraduate work should not be otherwise changed. The honors system would lead most satisfactorily to graduate work; it would provide the student with that background in metallurgical phenomena upon which graduate work in this subject can be based. In the end it would produce research workers in metallurgical science quite competent to advance the science of metals. While providing training in advanced physics, chemistry, and advanced mathematics, it would make no effort to produce abortive Ph.D.'s in solid state physics, or physical chemistry, who are not good metallurgists, physicists, or chemists. Granting a Ph.D. degree in any discipline (or any other degree) is but a momentary pause in an educational process that must be lifelong, and a man with such training can from then on grow in any direction he likes, however theoretical, however scientific, with confidence that as a metallurgist he is thoroughly well-grounded.

The heterodoxies

All this seems to be eminently sound, for the year 1959 and for the foreseeable future. Now we ought to inspect what might be designated as the new heterodoxies.

There are several schemes currently being urged upon the teaching profession with respect to engineering education at large and metallurgical education in particular. As to engineering education at large, about five major heterodoxies have become visible. The oldest of these, and in many ways the soundest, is in engineering physics. Students who have had this training to the bachelor's degree find many useful posts of employment, and their training offers a modicum of preparation for graduate work, while supplying industry with men a step above technicians. One can not quarrel seriously with it, and perhaps it should not even be included among the new heterodoxies. But nevertheless, this type of training can not supplant undergraduate training in the conventional branches of engineering.

The second is in engineering science. This scheme, currently practiced in a small number of schools, aims to provide the student with a broad background in all the sciences that apply to all branches of engineering. Although there has been much thought given to this, it seems to have little merit.

It is occasionally used to siphon off leading students into a discipline more demanding of their talents. It suffers from the same serious limitations that obtain in other examples of deviation—it is divisive, fragmenting, with little or no engineering point of view inculcated in the student, and serves an employment public so small as to be relatively unimportant. And those who find employment in those industries will find their preparation so broad and so remote from engineering as to leave them adrift in a unified industry. Such a training could in no way effectively replace training in metallurgical engineering.

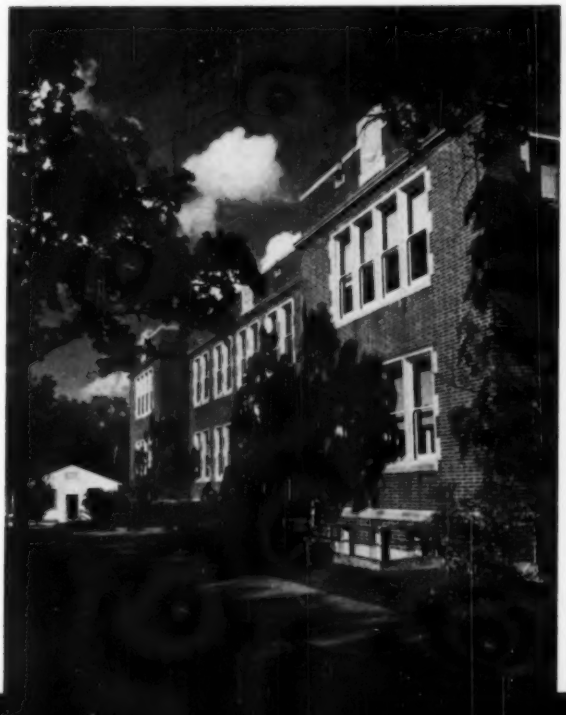
The third scheme is even more extreme, and is actually implemented in some important schools—to devise a general curriculum covering all branches of engineering. This can not be successful. It forces the curriculum into too many courses of the survey type; industry can not fruitfully use the training of men subjected to a curriculum neither fish nor fowl.

(Continued on page 676)

Above: New metallurgical engineering classroom and laboratory building, Colorado School of Mines, Golden.

Left: Metallurgy laboratory building, Montana School of Mines, Butte.

Below: Fulton Hall, University of Missouri School of Mines and Metallurgy, Rolla.



There can be no depth, and the demands for depth in every branch of engineering are increasing rapidly. It must certainly be admitted that some breadth is necessary in all branches of engineering. Perhaps an engineer should be shaped like a cone, broad at the top but narrowing pretty rapidly to a point at the bottom. A curriculum in general engineering can not be useful to the neophyte in industry, unless after graduation he undertakes a serious course of study in one branch of engineering, and of course this begs the question.

Another deviation, the fourth, is one in which the usual practice of a common group of courses in the first two years of an undergraduate curriculum is changed to a sequence lasting three years, with only a part of the senior year left for truly departmental work. It is said that the purpose is to broaden the scientific and engineering base. There are great risks in broadening—diverse subject matter is introduced at a fearful cost in depth in any one subject. Courses are introduced at the sacrifice of metallurgical courses, which, at least so far as metallurgists are concerned, have so little pertinency as to constitute a digression. For example, a two year course in engineering analysis, while a basic subject for electrical and mechanical engineers, has very little pertinency to the metallurgical engineer. And to take but one more example, under the general heading of the structure of matter, subjects in distant fields requiring a substantial amount of time, are introduced—polymers, plastics, ceramics, inorganic non-metallic solids, which though interesting and broadening, force a sacrifice in depth. Something between the extremes of broadness and specialization is the proper policy.

Materials engineering

And now to the fifth of the revolutionary ideas: prospects of a curriculum in materials engineering. The movement is questionable if it is taken to replace metallurgical engineering, and somewhat questionable on other grounds. If this curriculum is to be on the undergraduate level, the only way the important materials could be covered would be by means (again) of survey courses, each having little or negligible depth. It does not add to the logic of the argument to point out that there are features in science common to a number of fields that relate to materials, that a small measure of ductility can be imparted to ceramics . . . that defect lattices characterize all solids . . . that nucleation and growth processes occur regardless of whether the material is metallic or not . . . that there are some similarities among various materials as regards elasticity, viscosity and plasticity, and so on. However, the differences among materials are as numerous and as important as their likenesses, so that the study of each constitutes a discipline in itself. And little better can be said of graduate courses leading in their sum to a Ph.D. in materials engineering. For how can such a student procure the deep background of knowledge in chemistry, especially organic chemistry, to make him an adequate research worker in polymers, or in plastics, and at the same time obtain a background of excellence in metals, adhesives, refractories, concrete, or wood? A student, whether with a B.S. or a Ph.D., should go as deeply as he can in one subject. It may be argued that industry has needs for material engineers—the aircraft industry, for example. This may, in a way, be granted—though the need would be a small one. The engineering purposes of industrial effort would be better served by having a group of scientists and engineers (each deeply rooted in his own subject) making decisions through discussion of the best materials for a given purpose or application. And it goes without saying that the metals-producing industries would have little or no need for trained men in such a reputed discipline. It seems that the origin of this idea has been in the inadequacies of the educational system with respect to non-metallic materials. Why don't the ceramists fully explore their own field, why should the metallurgist, with all the unknown sea of knowledge still to be gained lying before him, undertake the duties of others and neglect his own?

The argument applies as well to all of the other branches of science and engineering that are assembled in the proposed, but illusory discipline of materials engineering. These remarks are directed primarily at the proposal for an integrated undergraduate curriculum in materials engineering, and of course in no way constitute an indictment of a single course that might be made a part of a conventional engineering curriculum.

The point that must be emphasized is this: a course in materials engineering, or in the other heterodoxies, will not in any way diminish or even affect the need for a continuing and constantly improved program in metallurgical engineering.

It seems to me that these educational experiments have much more than a touch of heterodoxy, that they are too extreme to be seriously considered as a general policy for the country so far as education in metallurgical engineering is concerned. No one will ever try to stop a college or so from practicing such curricula, and to have a few do so may be good. But the number of such colleges ought to be small and the great merit of metallurgical curricula should be preserved, with all efforts made for constant improvement.

Evolution rather than revolution

Evolution is the word, not revolution, at least not the kind we have seen thus far. And the steps to be taken in this evolution could easily be enumerated—but this is beyond the scope of this paper.

If the heterodoxy of today becomes the orthodoxy of tomorrow, then we must determine just when that tomorrow will be, when the mixture of science and engineering that we call metallurgy which serves us so well today will be outmoded, when continued improvement—evolution—will no longer serve and revolution will have to be brought about.

Every educator has, inherently, a deep unhappiness about education, springing from a feeling of the awful responsibility he has to the young—somewhat akin to that which every parent has to his children—and of the gross impossibility of preparing the young for their long future in all aspects of that precarious prospect. This runs through everything he does—the inadequate time which he can spend with each student, the scope of material which is presented in one way or another in courses, the general plan, the objectives of the curriculum at large. Some of these sources of unhappiness are possibly characteristic of this age. It is amply clear that many of the new ideas in education come from the desire to ameliorate this dissatisfaction. They will not succeed in doing so, for as such plans are put into action, the difficulty of doing the best for the young will appear again, perhaps with a greater distress. It is to the risk of this that these remarks are addressed.

Palmer Ricketts Building, Rensselaer Polytechnic Institute, Troy, New York.

Rockefeller Metallurgical Engineering Building, Case Institute of Technology, Cleveland.

Materials engineering
Metallurgical education

A PROGRAM IN MATERIALS ENGINEERING

Majors in chemical, metallurgical, and materials engineering are offered by a unified department at the University of Michigan.

by R. A. Flinn

AT a recent informal discussion of metallurgical engineering curricula, a leading educator asked half seriously what would happen if an academic metallurgical department was dissolved. The special interests of its students would be cared for by placing approximately 45 pct in a department of materials engineering, 40 pct in physics, and 15 pct in chemical engineering. The answer is quite straightforward—after a period of time, some of the faculty and students from these separate departments would find a common interest and request a new department to represent their common field of activity, this to be called metallurgy.

Although this is only a half serious example, it must be recognized that materials engineering is receiving increased attention as an engineering science. Of the six engineering sciences recognized by the ASEE, materials engineering is included, and metallurgy—as a subject—is absent. These considerations make it worthwhile for the metallurgist to examine the relative roles of materials and metallurgy. An industrial counterpart to the academic thinking is found in the aircraft, automotive, and electrical fields where the metallurgist usually advances from the position of chief metallurgist to chief materials engineer. Is there then a need for a separate degree in materials engineering? What would be the effect upon metallurgical engineering? One objective way of developing data is to review a situation in which degrees of metallurgical engineer, materials engineer, and chemical engineer are offered in the same department but under the leadership of separate program advisors. This arrangement has been accredited at the University of Michigan for some time. Let me hasten to add that this is in no way to be construed as a recommendation for general adoption—it is merely presented as a case study which has been quite satisfactory in teaching at Ann Arbor.

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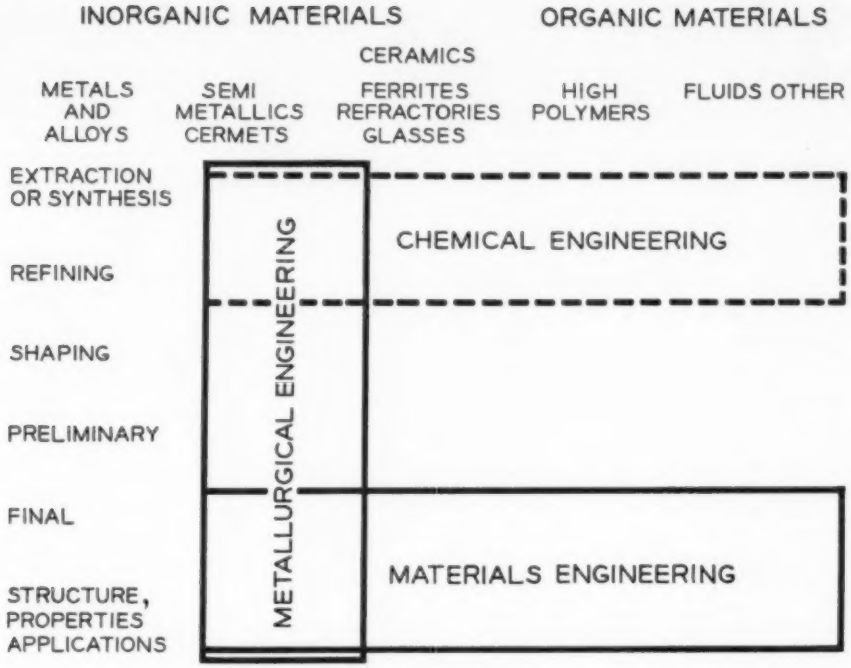
Relative objectives of materials, metallurgical, and chemical engineering programs

The objectives of a materials program can be summarized as an education in the structure and properties of all materials, particularly solids. The control of properties by structural transformations and the application of materials to engineering design are stressed.

Compared to metallurgical engineering, the increased knowledge of non-metallic materials and engineering applications is obtained by reduction in courses dealing with extractive and process metal-



Interrelation of courses in chemical, metallurgical, and materials engineering in the combined department at the University of Michigan.

lurgy. Compared to chemical engineering, reduction in courses dealing with processing, equipment design, and operations is made. These objectives are summarized in Fig. 1.

Curricula

Regardless of noble objectives, the practicality of any program is to be found in a study of its courses, faculty, students, and in its contributions of permanent value to the scientific and engineering literature.

The similarities and differences in materials, metallurgical, and chemical engineering curricula under study may be summarized under the divisions of basic science, engineering science, and program specialization.

Basic science: All programs require mathematics through differential equations with strong additional interest in statistics and advanced calculus; chemistry including analytical and a full year of physical chemistry; and physics of college level with strong additional interest in atomic and solid state physics. Chemical engineering and materials require a year of organic chemistry. The humanities are also represented, but this is outside the scope of this discussion.

Engineering science: All programs require chemical thermodynamics, structure of solids, electrical engineering, and engineering mechanics. Materials engineering requires more courses in dynamics and stress analysis. Chemical and metallurgical engineering prescribe additional work in mass and energy balances, rate processes, and so on, needed in processing calculations.

Specialization: Materials engineering offers courses in ceramics, glass, high polymers, and physical metallurgy. Metallurgical engineering offers courses in process and physical metallurgy. Chemical engineering requires courses in unit operations, plant design, and additional heat and mass transfer.

Opportunities for graduate study: While this report is chiefly concerned with undergraduate programs, it should be mentioned that continuing studies leading to M.S. or Ph.D. degrees are pursued in all programs.

Faculty and students

The department staff is made up of thirty-two professional appointments in chemical, metallurgical, and materials engineering. The common course in chemical thermodynamics is staffed in the main by chemical engineers, but with participation of metallurgists.

On the other hand, the courses in the structure of solids are staffed almost entirely by those with primary interests in materials and metallurgy. That the scope of staff interest is reflected in breadth of the courses may be seen by the following tabulation of principal research interests, as evidenced by recent publications: semiconductor materials; diffusion in liquids and solids; surface chemistry; interfacial energy of phases; creep and heat-resistant alloys; ceramic oxide—metal reactions; complex metallic carbides in metal systems; high polymer properties; nuclear metallurgy; solidification; cast metals; wear, fatigue, and abrasion; and solid-solid reactions.

Engineering students at the University of Michigan are classified in one or more programs after the freshman year. The present department distribution of under-graduates is: materials, 10 pct; metallurgy, 30 pct; and chemical engineering, 60 pct.

It is surprising that despite the increasing and widespread interest in materials, both academically and industrially, a larger number have not elected the program. One reason given by the students is the small number of positions specifically requesting materials engineers. The principal reason for this is the newness of the degree—most firms, when told of the program are very interested in its graduates.

Results

The existence of materials, metallurgy, and chemical engineering curricula in the same department has had interesting effects upon curricula, staff, and students.

Effects upon curricula: The effect upon the three mentioned must be considered first and then the influence upon other curricula, in the teaching of so-called service courses, may be examined.

The materials engineering program depends upon good intensive teaching in the structure and properties of metals, ceramics, and organic materials. To accomplish this, actual research in a field or at least a thorough knowledge of the recent literature is needed. There are few, if any, single individuals with sufficient background to teach all three fields. Therefore, the gathering of metallurgists, ceramists, and chemical engineers in one department automatically provides a staff to draw upon.

The metallurgy program in turn benefits from the strong teaching background of the chemical engineers in dealing with courses in thermodynamics and unit operations. In obtaining a broader understanding of the solid state, the influence of the staff interests in semiconductors and ceramics is most helpful.

The chemical engineering program, although very strong in its own right, benefits from assistance in problems in materials, particularly in some of the situations in nuclear reactors, corrosion, and high and low-temperature behavior.

Other programs, such as mechanical, electrical, aeronautical, industrial, and civil engineering, benefit in the breadth of the *service* courses which are offered. It has been possible to develop a sophomore level course called *The Structure and Properties of Engineering Materials*, using Van Vlack's text in which the important properties of metallic, ceramic, and organic materials are related to the basic structures. In this way, the other departments do not have to seek out and correlate three different courses in metallic, ceramic, and organic materials.

In addition to providing an important service to other engineering students, this course acquaints many with the intriguing applications of basic science to problems in materials for the first time. As a corollary, the quality and number of students interested in both materials and metallurgy has improved since the development of this course.

While the problem of service courses is always good for a separate debate, it should be pointed out that of all the groups on an engineering campus, the metallurgists are the best trained to teach a course in materials. If this responsibility is *not* accepted and discharged on a broad basis, it is quite possible that another department called materials or molecular engineering or solid state engineering will be organized. This could be a first step in the scattering experiment discussed in the introduction.

Effects upon staff and students: By supporting the three curricula in one department it is possible to encourage *horizontal* staff and student interests without hindering *vertical* interests. By horizontal and vertical, the direction of grouping in Fig. 1 is referred to. In other words, in most institutions it is easy to place a chemical or metallurgical engineer on the staff. On the other hand, with this traditional approach it is harder, for example, to place personnel with the following combined interests: 1) semiconductors and process control; 2) surface properties, diffusion mechanisms of metals and ceramics; and 3) ceramics, glass, and metals. People with this type of background have been easily assimilated by the combined curricula.

At the end of their freshman year, students often find it difficult to decide between departments of chemical and metallurgical engineering. These departmental walls often lead to serious differences in prerequisites and lessen the possibility of combined programs. By contrast, in many instances it is better for a student planning an industrial career to complete the requirements for bachelor's degrees in both chemical and metallurgical engineering in four and one-half to five years than to advance to the master's level in one or the other. This can readily be done when inter-departmental correlation of courses is present.

Conclusions

As mentioned earlier, it is not the intent of this review to suggest a model relation between materials and metallurgy. The roots of any academic department are deep and divergent, and it would be extremely difficult, even if desirable, to establish the horizontal system of education in materials by decree.

In any case, it does seem important to develop a center of interest in materials, with strong participation by metallurgists, for three reasons: 1) the correlation of development in other areas of solid state science which affect metallurgy—semiconductors and cermets, for example; 2) the academic need for courses in materials; and 3) the industrial need for materials engineers. This participation would strengthen any metallurgical group.

The price of liberty in our profession is not eternal vigilance, but rather continuous service to all our colleagues and all our students. If we, as metallurgists, marshall our energies to this end, we shall lead, rather than be dominated by, any materials program.

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Materials engineering
Metallurgical education

INTEGRATING THE TEACHING OF PROCESS AND PHYSICAL METALLURGY

A long look at today's metallurgy shows that it is more logically divided into fields based on scientific principles rather than the traditional technology. It is here shown how thermodynamics, kinetics, and structure may be taught as principles, with applications in both physical and process work.

by C. Law McCabe

DURING the course of deliberations held in the past three years on the undergraduate curriculum change which the Dept. of Metallurgical Engineering at Carnegie Institute of Technology is making this Fall, some thoughts arose which might be of interest to teachers of metallurgical engineering and to metallurgists in general. In order to give perspective to these thoughts, it should be noted that the curriculum adopted follows the tradition at Carnegie in training undergraduate metallurgists as broadly as possible in the science and engineering of metallurgy.

There are two rather contradictory trends in metallurgical engineering education today. One trend is toward unifying and integrating the curriculum within a department (or, in some cases, in the whole engineering school); the other is to allow options so that a student may specialize in a particular area of metallurgical engineering. Both trends, in part, are an effort to cope with the ever increasing amount of scientific and engineering knowledge in metallurgical engineering. At Carnegie, the first trend is favored. Therefore, what has been done in the new Carnegie curriculum is to integrate the individual courses and to arrange the presentation of material in a more logical sequence. In addition, *honor courses* have been added in the senior year for men who wish to continue their studies in graduate school.

The general thesis discussed here is that the teaching of physical and process (*extractive* or *chemical*) metallurgy could be integrated much more than is currently the case in most departments of metallurgical engineering. The degree to which this thesis has been and will be executed is the province of the professors in each department. As a matter of fact, most changes in departmental curricula occur through day to day changes in course content by the professors, acting both alone and informally in small groups. Formal curriculum changes, therefore, in many cases, merely acknowledge a *fait accompli* and, in addition, allow a logical scheduling of topics not possible in the existing curriculum.

Course division rooted in the past

In most schools, the metallurgy curriculum has traditionally been divided in several ways—ferrous and nonferrous, or process and physical. The reason for this division is that the metallurgy curriculum has its roots in the time when technology was dominant; at that time it was logical to divide the curriculum along technological lines. Everyone knows that as more powerful scientific and engineering techniques have been applied to the field of metallurgy, many seemingly diverse subjects

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have been found to be closely related. However, in the teaching of metallurgy the tendency has persisted to keep the identity of the courses in the categories set by technology many years ago, even though the course content has markedly changed.

The general suggestion here is to integrate the metallurgy curriculum by teaching fundamental principles and techniques relevant to metallurgy in a logical sequence, and to use (at the time the principle is developed) examples from the whole field of metallurgy for illustration and problem solving, whenever this is appropriate. Of course, it is recognized that this is already being done to some extent in some graduate and undergraduate schools. However, the trend is not nearly as strong as it should be, largely because of the reluctance to break out from traditional course titles and, in any given course, to cross freely between process and physical metallurgy.

Integration promotes efficiency

The use of examples from the whole field of metallurgy to illustrate a fundamental principle results in a time saving, because the necessity for different professors to develop the same principle is eliminated. The problem of time is most important in the teaching of metallurgical engineering because of the many scientific, engineering, and technological advances which are being made. This has meant that professors of metallurgical engineering have continually taken material from their graduate courses and placed it in their undergraduate courses, a process actively underway for at least the past quarter of a century. The result has been to eliminate a great deal of the so-called descriptive matter in the undergraduate curriculum. It would seem, however, that the best departments of metallurgy and metallurgical engineering are close to the danger point in eliminating this type of material, since much of that which has survived is essential for a successful engineering career for the *majority* of those men taking the bachelor's degree. As teachers of metallurgical engineering, we must not only teach basic science and engineering, but we must also relate these fundamentals to the solution of practical metallurgical problems so that the average undergraduate student will be able to use the principles in his professional career. Clearly, then, we must look for more efficient methods to teach the ever increasing amount of subject matter, both in engineering and in science.

In response to the obvious rejoinder to this proposal—that repetition is an essential part of successful teaching—one can say that repetition of topics could and would be planned, but planned intelligently from the standpoint of the best teaching, rather than by the chance that the same basic principles or discipline is used in two areas of metallurgy—the present basis for repetition. And, as time goes on, we must have less and less repetition, for lack of time.

A second aspect of further curriculum integration is that the topics covered can be developed in a more logical sequence. It certainly is true that a great deal of progress has already been made in doing just this. For example, the two classical courses, ferrous production metallurgy and nonferrous production metallurgy, have, in many universities, been replaced by one course which treats these topics as a coherent unit. However, it is felt that even this step in integrating the teaching of process metallurgy is not the end but that both process and physical metallurgy can be further integrated.

Principles as a base—not technology

The success or failure of building a metallurgical engineering curriculum around principles rather than technology depends upon a detailed analysis of what constitutes the field of metallurgical engineering, in order to set goals, and then a construction of a suitable curriculum to accomplish the desired end. As anyone who has done this knows, it is a time consuming process and the character of the analysis and the resulting curriculum is to a great extent dependent on the particular group of professors involved. As a matter of fact, this is the way it should be, since the execution of the program rests squarely on the professors and for them to be forced into an arbitrary arrangement of courses and content would result in ineffective teaching, since it is human nature to do best when one is following one's own inclinations. Therefore, the objective here is to provide raw material for future discussion. We will now examine some concrete examples in which physical and process metallurgy can be integrated. For purposes of clarity we separate the topics having common roots in process and physical metallurgy into three familiar categories—thermodynamics, kinetics, and structure.

Integration in thermodynamics

Topics in physical and process metallurgy having common roots in the discipline of thermodynamics are plentiful. For example, the subject of phase diagrams has broad application in physical and process metallurgy which defies complete documentation. Except for a brief, once-over-lightly in physical chemistry, this subject is usually taught to metallurgists as part of a physical metallurgy course.

The examples given, then, are usually exclusively metals. It seems preferable to teach the subject with the aid of examples from both metallic and nonmetallic systems so that, from the outset, the student will realize the full potential of the technique in diverse fields. Another general topic which is of far reaching importance in both physical and process metallurgy is the determination of the concentration of components in two phases which are in equilibrium with one another. For example, in process metallurgy the distribution of silicon between metal and slag is important; in physical metallurgy the distribution of molybdenum between an alloy phase and a carbide phase is important. To estimate or calculate the distribution of the solute in both of these examples requires a knowledge of the appropriate free energies of formation and activity coefficients. Since the metallurgist deals with distribution equilibria involving metal oxides, carbides, sulfides, nitrides, chlorides, fluorides and silicides, it seems logical then to carry out the discussion of the determination and tabulation of the free energy of formation of the above groups of compounds as a unit. Intermetallic phases might well be included. Furthermore, all of the topics involved in the determination of the appropriate activity coefficients could also be developed as a part of this same course. The starting point would, of course, be determined by the background of the particular class.

The basic topics that would be involved are the definition of the Henrian and Raoultian activity and

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activity coefficients, the Gibbs-Duhem integration, and methods for changing standard states. A wealth of applications for such a development of solute distribution are available and, indeed, the applications help in teaching *descriptive metallurgy*. A closely related topic, which could be taught in an advanced undergraduate course, is the estimation of activity coefficients in ternary solutions. By making some simple assumptions about solution behavior, Alcock and Richardson have presented a method of calculating the activity coefficient of a solute in a ternary solution from a knowledge of the appropriate activity coefficients in the binary solutions involving the three components. Their method applies both to liquid and solid solutions and thus it is applicable to systems in both physical and process metallurgy. Furthermore, for silicate systems and for carbide systems, Richardson has applied the Temkin model for mixing in order to explain the power relationship between activity and mole fraction in these systems. The model assumes that the free energy of mixing arises only from the mixing of the metal atoms on a fixed lattice of carbon, or metal oxides on a fixed lattice of silica. Here the same basic statistical-mechanical treatment leads to applications in both physical and process metallurgy.

Electrochemistry: A very important part of both physical and process metallurgy deals with electrochemistry. For example, the process metallurgist produces metals by electrolysis and both the physical and process metallurgist are interested in the electrochemical nature of corrosion, since the former deals with the dissolution of metals and the latter with the dissolution of minerals. Electrochemistry is developed to some degree in the courses which the undergraduate metallurgist normally takes in the chemistry department. However, it is usually essential for the metallurgy department to review the subject and to apply it to the special materials and processes which the metallurgist encounters. For example, the Pourbaix diagrams are a convenient way of discussing both the leaching of ores and the corrosion of metals, but their construction and use are not covered in chemistry courses and the metallurgy curriculum must carry this load. Further analysis of the applications of electrochemistry in metallurgy would probably lead to support for electrochemistry to be taught as a unit of the metallurgical curriculum.

Integration in kinetics

Both the physical and the process metallurgy professor is likely to start any discussion of kinetics by first referring to the kinetics section of a physical chemistry course which the students have taken in the chemistry department. The two professors, physical and process, will develop many of the same points in leading students from the chemist's to the metallurgist's viewpoint on kinetics. Both professors will make the point that the metallurgist nearly always deals with heterogeneous systems, not with the homogeneous systems normally found in chemical kinetics. Furthermore the combination of high

Top: School of Metallurgical Engineering, Purdue University, Lafayette, Indiana.

Middle: Mines and Metallurgy Building, University of Minnesota, Minneapolis.

Bottom: Metallurgy Laboratory, University of Illinois, Urbana.

temperatures and the heterogeneous nature of metallurgical reactions more often than not cause transport processes, rather than the chemical reaction, to be rate controlling. This discussion leads directly into a discussion of the *doctrine of local equilibrium*, which has been put to use so beautifully in metallurgy by Dr. L. S. Darken. Local equilibrium can be illustrated using the mechanism of pearlite formation in steel as an example from physical metallurgy and the mechanism of metal sulfate formation from process metallurgy. It seems only natural then to introduce the subject of the kinetics of high temperature reactions in a way which includes both physical and process metallurgy examples.

Diffusion: The topic of diffusion is a most important factor in the kinetics of both physical and process metallurgy. Although it may not be appropriate to include as a unit all of the discussion of diffusion found in both process and physical metallurgy, it does seem worthwhile to include in the elementary physical metallurgy sections on diffusion some simple cases of rates in process metallurgy which are determined by diffusion. Two such cases from process metallurgy are, the oxidation of metal sulfides, which has as its basis the same theoretical discussion which precedes the oxidation of metals; and transfer of a solute across an interface being limited by the rate of diffusion through a stagnant film, which has as its basis Fick's first law. On this latter subject, a more detailed discussion of transfer between phases being limited by diffusion would be left to a special process metallurgy course, but the introduction of this subject when Fick's laws are developed and applied would be of great help to the process stem in metallurgy.

The subject of nucleation in phase changes is of vital importance in both physical and process metallurgy. As a matter of fact the freezing of pure metals and alloys, a subject which is of prime importance in process metallurgy, has been found to be an excellent illustration for the theoretical development of homogeneous and heterogeneous nucleation. Indeed, this has been a part of the physical metallurgy curriculum at Carnegie for many years and is an excellent example of the general thesis here—that a topic which has been developed from a theoretical point of view should be illustrated by the best examples available, whether they be from physical or process metallurgy.

Integration in structure

The third and last general topic which will be discussed is structure. From what follows you will note that the term is used loosely.

A fundamental consideration in the subject of structure is the nature of the solid state, where the simple perfect solid and X-ray diffraction are introduced. The *perfect solid* normally serves as the basis for a discussion of the effect of lattice imperfections and plastic deformation on the properties of solids. At this point it seems logical to bring in the model for glasses and liquids, since this model is a modification of the perfect solid. The introduction of the liquid state at this time can be accomplished with a saving of time over that required to introduce the subject in a process metallurgy course, since the class is ripe for the liquid state model after having just finished the subject of imperfections in solids.

Certainly one of the most important sections under the topic of structure is the nature of bonds. Again, in the physical metallurgy course at Carnegie the subject of chemical and physical interactions between atoms has been developed by reviewing some of the material on this subject which has been introduced in the physical chemistry course. Then ionic, covalent, and molecular bonds, as well as the metallic bond, are discussed in considerable detail. It is obvious that this development serves well the needs of both process and physical metallurgy.

Closely allied with the nature of bonds are the electrical properties of solids and liquids. At Carnegie, the course in physical metallurgy does indeed cover the electrical properties of metals, covalent crystals, molecular crystals, ionic crystals, and semiconductors. In addition, the electrical properties of these substances when liquid are discussed. This foundation is of great help to the process metallurgy stem when the subject of the structure of slags, as related to their physical and chemical behavior, is introduced. In addition, the way is paved for the topic of fused salt electrolysis. Furthermore, the discussion of the electrical properties of molten metal sulfides in the present Carnegie physical metallurgy course provides an excellent example of how research in process metallurgy has provided a material possessing certain desirable semiconduction and thermoelectric properties which are not found in other materials. Such discussion helps to show the student the interdependence of physical and process metallurgy and the importance of metallurgical research in the growing materials field.

The materials engineering question

The above discussion of the integration of physical and process metallurgy is relevant to a topic currently on the minds of teachers of metallurgical engineering. The question is whether or not metallurgical engineering should transform itself into materials engineering. This question has been the subject of much discussion and, indeed, much misunderstanding. It is obvious that for an established metallurgical engineering department suddenly to make this transformation would inevitably result in the curriculum becoming little more than a series of survey courses. As any professor knows, such an education is next to valueless. A great deal of scientific and pedagogical research must be completed before the proposed transformation can be established as practical and desirable. As a matter of fact, one of the most pressing current problems for departments of metallurgical engineering is finding the time to go deeply into all of the subjects which constitute metallurgy, let alone the whole field of materials. For the present, then, it seems preferable for an existing department of metallurgical engineering to do its utmost to integrate and refine its courses, so that it does an excellent job with metallurgy. This alone is a mammoth task and it is made even more so by the fact that metallurgical knowledge is accumulating so rapidly.

In conclusion, it is fair to say that teachers of metallurgical engineering are steadily evolving an undergraduate curriculum which effectively deals with the heart of the scientific and engineering principles associated with metallurgy. As a means of attaining this goal, the integration of process and physical metallurgy courses has been investigated and specific examples have been discussed.

TEACHING MATERIALS SCIENCE TO ENGINEERS

Every engineer is, in a sense, a materials engineer. Described here is a course designed to give students other than metallurgists and ceramists a firm foundation in materials science.

by J. N. Hobstetter

LIMITATIONS imposed by our lack of knowledge of the properties of materials—solid, liquid, or even gaseous—constitute the worst bottleneck in the growth of our complex technology. There is an insistent cry for materials which will meet stringent or even bizarre conditions in which modern devices must often operate. New uses and unconventional treatments have been developed for known materials, but even more, new and untried areas are being explored, often haphazardly, in hopes of turning up the substances which will bring the new technology into hand. These substances may range from delicate crystals that provide almost noise-free amplification of the tiny radio signals from galaxies 10,000 million light years away, to the rugged structures that will withstand conditions in the reaction chambers and nozzles of rocket engines with several million pounds of thrust.

It is evident that these new material demands have created a need for education that far transcends the bounds of conventional courses in metallurgy or ceramics. Furthermore, it is evident that since material limitations now affect all engineering and science disciplines, education in material properties should no longer be confined largely to metallurgists and ceramists, but must be spread throughout the science and engineering area.

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Materials science for electrical . . .

Consider the situation in a few of the more important engineering disciplines: The electrical engineer of today can scarcely be abreast of his field without detailed knowledge of semiconductors. This knowledge must embrace more than specifications of circuit elements such as transistors. If he is to fully exploit the opportunities that these materials make possible, he must know how their useful properties arise. He must also know how conditions such as stress, strain, extremes of temperature, and chemical changes affect their behavior. The same may be said for ferrites, which have already assumed vital roles in magnetic and microwave circuits and as memory devices. The newer ferro-electrical devices and maser amplifiers are asserting similar claims.

. . . mechanical . . .

A demanding frontier for today's mechanical engineer is embodied in new power generating devices such as jet engines, other gas turbines, and pre-eminently, the high-thrust rocket engine. Very often, his designs are limited by mechanical property barrier. On one hand, this may be the poor hot strength and creep resistance of a conventional, easily fabricated material, or on the other, it may be the difficulty in fabricating a new metallic, ceramic, and or ceramet which does show improved hot strength. His knowledge of the material's properties and, more particularly, of the means by which they may be modified and controlled, is crucial to getting top performance from whatever material is available.

. . . and chemical engineers

The chemical engineer is under similar constraints in his designs. Chemical processes operate at ever

higher temperatures and pressures, and often involve highly corrosive materials, such as the liquid sodium used in nuclear reactors. Materials for shielding these reactors may also be within his responsibility. He must manufacture new fuels which will power rocket and other engines, and this entails storing, pumping and handling them, often at new low temperatures. These conditions are extreme and unconventional—in relation to known technology. Again, only a thorough knowledge of possible material properties and their control can lead to the best designs.

It is evident that this same statement can be made in regard to almost any engineer or scientist today.

The realization of the limitations in materials technology has brought with it a widespread reexamination of engineering curricula. In most engineering areas, except possibly in metallurgy and ceramics, education in materials has been found deficient. Many schools are experimenting with new, more general materials courses for all engineers. An approach to such a course, which has proved workable and useful in our engineering schools during the junior year, is given below.

No course in this field could succeed if it attempted to produce a mere compendium of the properties of a wide variety of materials nor would such a course be desirable, even if possible within the curricular limitations usually available. Clearly, the student must be equipped with a fundamental understanding of how properties of materials depend on their structures, and of the principles governing the formation and control of these properties. Armed with such knowledge, he should be better able to evaluate the potentialities of both materials now known and those that will become available in the future. He will also understand to what extent those properties are amenable to modification and control.

Properties of materials

In designing a course to meet these requirements, the first consideration is to remind oneself, from a fundamental point of view, how the properties of materials arise. Ultimately, all properties are a function of the generalized forces that atoms exert on one another; these forces arise entirely from the configuration of the electron clouds surrounding the atomic nuclei, but this configuration is determined by the nature and the charge on the nuclei itself. In response to these forces, the atoms tend toward aggregations of various complexities. In many cases, the aggregation is the orderly and symmetrical array of atoms that we call crystals. In other cases the atoms may associate in intricate but largely nonsymetrical patterns that constitute large molecules. In still others, the aggregate may be largely random, as it is in glasses and some other ceramic materials. The properties of these aggregates depend on two factors: the nature of the forces that hold them together, and the geometry of the spatial arrangement of the atoms. The first of these controls what may be called the intensity of the various properties, while the latter determines whatever directionality they may show. Finally, familiar materials consist of aggregates of these crystals or molecules, arranged either randomly or in varying degrees of perferential alignment, so that final properties are those of the single crystals or molecules but as modified by their mutual interaction. The purpose of our course is to explore in detail the fundamental interrelation between properties and structure, so as to uncover the principles that govern the properties of all materials.

The course is called *Science of Materials*. The first major section is devoted to a discussion of the structure of materials—a review of atomic structures of the elements, emphasizing the use of the quantum numbers to distinguish among the possible stages of electron distribution. It is important to avoid getting mired in spectral or fine structural complexities which cannot be adequately treated, and which do not contribute in any important way to engineering properties. It has been found neither necessary nor useful to refer to the old Bohr theory. Wave functions and the geometry of orbital electron distributions can be made sufficiently clear to support the subsequent discussion of interatomic bonding.

Interatomic bonding

The section on interatomic bonding is both crucial to the course and also, conceptually, the most difficult. Only a descriptive treatment can be attempted at this level. We have found it best to treat four important types of bonding in distinct categories: 1) van der Waals, 2) covalent, 3) ionic, and 4) metallic. The simpler hybrid orbitals of the covalent bond and simple band theory of metals, semiconductors, and insulators are presented. It is emphasized that these four types of bonding are ideal cases and that most real cases fall among them.

The stage has now been set for discussing aggregates of atoms, and first among these are molecules and radicals in which directional covalent bonds are prominent. Some of the more important 8-N structures are reviewed, but attention is increasingly directed to organic molecules and polymers which are explored rather thoroughly with respect to their structure. Silicate glasses and ceramics are also carefully surveyed as a typical example of many other crystalline or quasi-crystalline ceramics, which are treated more briefly.

The non-directionality of van der Waals, ionic, and most metallic bonding can produce only densely packed arrays of small units showing periodicity of structure. For the purpose of describing these structures, the simpler aspects of crystallography are presented. These include lattices as scheme of repetition, patterns of atoms to be repeated, crystallographic coordinates, planes, directions, forms, multiplicities of zones, stacking orders in close-packed crystals, and examples of all the basic, simple crystal structures. This completes the first section of the course.

Structure and properties

The second major section discusses the relation between structure and properties of pure or nearly pure substances. We begin with the relation be-

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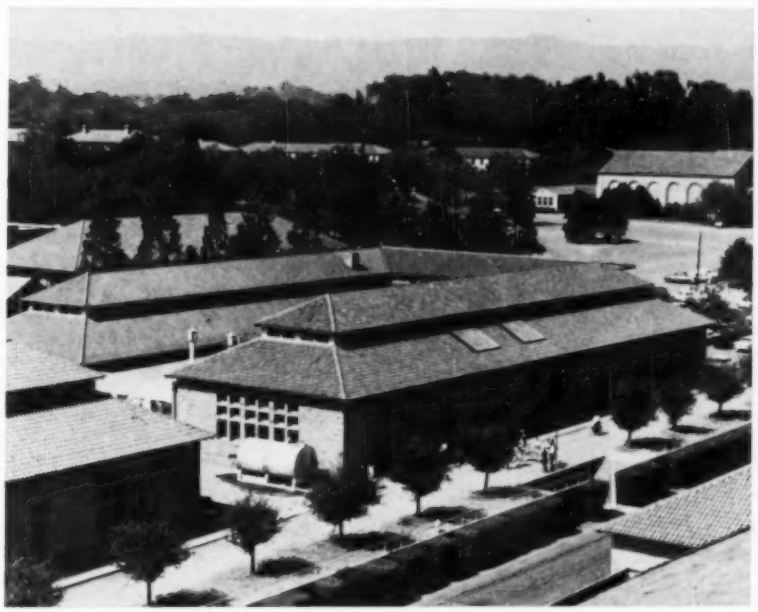

tween structure and mechanical and dielectric properties of polymers and ceramics, and then pass to the phenomenology of electrical conductivity of nearly free electrons in metals, relating their mobility to the mean free path of the carriers. The latter is, in turn, related to thermal vibrations, to impurity content, or any other interruption in crystal periodicity. A simple extension is made to semiconductors, where the same treatment applies to the conduction electrons and where hole conduction also plays its vital role. Extrinsic conduction in *n*- and *p*-type semiconductors is discussed, and this leads to a brief description of rectifying junctions, diodes, transistors, solar batteries and other semiconductor devices.

Following this is an explanation of magnetic phenomena. The electronic mechanism of dia-, para- and ferro-magnetics is explored to lay the basis for understanding the behavior of magnetic metals and alloys and the magnetic oxides. It is also convenient to introduce the ceramic ferro-electric materials at this point because of their phenomenological similarity to ferro-magnetic materials.

The discussion of nearly pure substances ends with an account of their mechanical properties. First to be considered is the elasticity of pure crystals in which the full tensor expression of Hookes law is developed and applied to the more important crystal systems. Understanding of the components of the stress and strain tensors is an important objective in this development. Response of crystals to various stress tensors is discussed, and the averaging of crystal elasticity over all orientations to yield the isotropic properties of random crystal aggregates is shown.

Plasticity is next treated, first from the phenomenological point of view. We describe slip and slip systems, the critical resolved shear stress, work-hardening, creep and fracture of single crystals and polycrystalline aggregates. There follows a rather detailed but descriptive account of dislocations, showing why they are necessary, what their properties are, and how they account for observed phenomena.

Alloying

The third major section deals with multicomponent systems; that is, with the effect of alloying in the most general sense of the word. We begin by describing liquid and solid solutions and lead easily to the concept of a thermodynamic phase. The ideas of components, state, and state variables are then introduced and the Gibbs phase rule is derived and explained. Throughout the ensuing discussion of binary phase diagrams, the phase rule is constantly invoked to show their possible forms. We develop and exhaustively discuss simple eutectic and peritectic behavior and lead gradually to diagrams of considerable complexity. Emphasis is always on the prediction of equilibrium microstructure from the diagrams, and on the relation between these microstructures and properties. The simple rules of Hume-Rothery, which interpret the similarities and differences between phase diagrams in terms of fundamental atomic properties, are cited as means of extending prediction to new, unexplored alloy systems.

Kinetics

The fourth and last major section deals with the general topic of kinetics, particularly the rates of phase transformation upon which heat treatments depend. The fundamental mechanism involved in diffusion is discussed in some detail, from the standpoint of mechanism and magnitude, as a function of temperature. There follows a descriptive but thorough treatment of the nucleation of a phase transformation at sub-critical temperatures and of subsequent growth of the particle. In this way the T-T-T curve is derived. We are now in a position to show how heat treatment can modify the equilibrium microstructure, and, therefore, the properties of an alloy. This technique is illustrated with age hardening of dural and the isothermal decompositions in steel, but emphasis is on the generality of the technique. The martensite reaction and the effect of alloying elements on hardenability are also discussed. The alloy steels provide a fine example of how a good portion of the knowledge gained in the course can be put to use: the control of microstructure and, with it, the development of an array of properties of high utility.

The course ends with a fairly brief discussion of corrosion as a kinetic process, showing some of the principle mechanisms and means used to control it.

Conclusions

It will be apparent that the foregoing, when packed into a single-term course, produces a very large density of information. Many curricula do not provide for more than a single term at this time, and therefore this density must be tolerated. To make the course workable as well as useful, emphasis on general principles rather than details or examples is vital. Even in a two-term course the density would remain high, but there would be opportunity for enrichment of the content with fuller treatment and more examples. We believe the importance of this subject demands a two-term course, and that inevitably this will become the rule in engineering curricula.

Finally, we wish to note that, notwithstanding a number of materials texts that have appeared in the last two years, most are quite unsatisfactory for use in a course like the one described. One might suspect that the large demand for texts occasioned by the recent growth of materials science courses in engineering curricula led to offerings of the most readily available manuscripts—without much research into needs in this field. Some of the new books are sketchy in content or fail to penetrate the fundamentals. In others, one has the impression that a few chapters on non-metallic substances have been grafted onto metallurgy texts in order to bring them under the materials classification. Still others supply a great wealth of detail along with a fairly fundamental treatment. These latter can be used in this course, but at the cost of some lack of clear emphasis on the fundamental principles upon which the course must necessarily dwell. New text book offerings in this field are still very welcome and will be watched with interest.

Materials engineering
Metallurgical education

THE FUTURE OF PROCESS METALLURGY

Process metallurgists—cast adrift by the materials engineers and ignored by the chemicals—are still needed and should be trained to complement, rather than conflict with, allied fields.

by T. B. King

A discussion of educational methods should not be taken to imply that there is necessarily much wrong with the present system. Continuous reappraisal, agonized or otherwise, is good for educational *liberals* and *conservatives* alike. For we have to convince ourselves, in the atmosphere of the many pressures that are exerted upon us, that our present methods are indeed the most satisfactory.

The process metallurgist, and indeed any other kind of metallurgist, is not fairly regarded as a scientist. By definition he is an engineer, whether or not the word appears in his title, but he is both a scientifically-trained and a scientifically-minded engineer. He is concerned, as are other engineers, with things, with materials, structures, devices, with the applications of science rather than its own pursuit. An engineer makes, specifies, processes, or uses materials of many different kinds. In recent years it has become evident that the making of useful raw materials, such as metals, is a smaller part of the whole field of metals than many process metallurgists allow themselves to think. In fact, the only justification for regarding process metallurgists as in any way a separate class of engineers is that there does exist a demand for people combining a broad knowledge of metals with training in physical chemistry, thermodynamics, and the principles of chemical engineering. The argument that there can only be one type of metallurgist, whose training should fit him equally for processing and utilization in industry, may be good in principle but is liable to be poor in practice.

Process, extractive, chemical metallurgy

The scope of process metallurgy can be defined in many different ways, but a commonly accepted interpretation is that it covers all the separation processes from the initial ore to the pure or alloyed metal, cast in a semi-finished form. The term extractive metallurgy probably defines its scope somewhat better, since *process* metallurgy is often confused with metals processing, the latter being taken to mean the shaping of metal to further semi-finished or finished products. The field is a little more restricted if the name *chemical* metallurgy is adopted, since this would seem to exclude purely physical processes which form the backbone of that portion of extractive metallurgy which is often included in mineral engineering. Although there is something to be said for this last name, it would not be correct to exclude the beneficiation and concentration of ores.

Before looking at the future of process metallurgy, we should consider its past and present. A good reason for so doing is that one is better able to appreciate its existence as a separate field and to see wherein there may be deficiencies in present teaching methods.

All engineering subjects have as a reason for their existence the fact that there is appreciable industry demanding such training. There would be little justification for the existence of metallurgy as a separate engineering discipline were it not for the fact that metals comprise the largest group of useful engineering materials. If metals were not produced in such large quantity there would be even less justification for regarding process metallurgy as important enough to be distinguished from physical metallurgy.

Processes in the metals industry

The history of the metals-producing industry is one of continued process development for a few basic metals, principally steel, copper, lead, zinc, tin and, in more recent years, aluminum and magnesium. In the last two decades there has been a demand for quantity production of many newer metals. For most of these, processes applicable on a small scale have long been known, but the incentive for quantity production methods has had to await the discovery that these metals have useful properties when carefully purified. Industrial production of reactive metals such as uranium, thorium, titanium, zirconium, hafnium, columbium, and the rare earths has meant the introduction of many techniques new to metallurgists and modifications of existing methods. Ion exchange, solvent extraction, chloride reduction, and vacuum methods are examples of techniques that were familiar enough to researchers, largely

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in chemistry, but with which metallurgists had to acquaint themselves.

At the same time, there have been continued improvements in existing techniques for producing the more common metals. Demands for increased quality and cheaper production have kept process metallurgists busy in the steel and large nonferrous industries.

The increased use of metals such as sodium, potassium, and calcium as heat transfer agents and reductants forced metallurgists to realize that these metals were largely produced by the chemical industry. Metals which were by-products of the production of other metals such as lead and zinc, have now assumed increasing importance, particular examples being germanium and bismuth. This in turn has required metallurgists to re-evaluate the present production methods.

There is a fairly general feeling that metallurgists (and particularly process metallurgists) have taken a smaller part in these developments than was their due. Is this because of basic deficiencies in the way in which our process metallurgists are trained? The answer might be a qualified "yes," but there are many factors to be taken into account. We must not forget that these developments are largely a result of our concern with national defense; though the transistor and nuclear power have major peacetime applications, the incentive for initial development was generated through fears for survival. Large sums of money were made available for crash programs that existing industry was unlikely to finance, and thus developments in the metal-producing field, as in many others, have proceeded at a very rapid rate.

Supply and demand

The supply of metallurgists capable of handling process work has been less than the demand; thus the industries have turned to other fields, principally chemical engineering and chemistry, for their process engineers. There is an added reason why they should have done so; companies other than the steel and large nonferrous producers have entered this field in increasing numbers, chemical companies in particular. It is natural for chemical companies to turn to chemists and chemical engineers to develop and operate their processes. Nor should we be surprised at this trend; many of the pioneer process metallurgists were really well trained inorganic and physical chemists.

The question to be examined is whether or not process metallurgists would have been able to contribute more to this expansion in the metals producing industry if they had been available in sufficient numbers, and if the industries concerned had recognized where they ought to go for their engineers. Perhaps the answer is to be found in the fact that increasing numbers of chemical engineers have found their way into an ancient strong-hold of the metallurgist, the steel industry. It would be idle to pretend that none of them have a place there, and that they are occupying positions properly filled by process metallurgists, but perhaps this trend indicates a deficiency in process metallurgists. It may be true that the chemist and the chemical engineer can supply something that the present process metallurgist lacks, particularly in the design and operation of newer processes. In some schools, we may have overreached ourselves in expanding and broadening the curriculum in structure and properties of metals at the expense of processing. At the same time, the basic metal-producing industries have been negligent in their use of process metallurgists. There has been no great incentive to attract students into the field, for the jobs given to them have often not been commensurate with their talents.

Teaching process metallurgy

The pattern of education in process metallurgy has changed even as the industry has changed. But to a large extent the change is a result of post-mortem rather than prognosis, or even diagnosis.

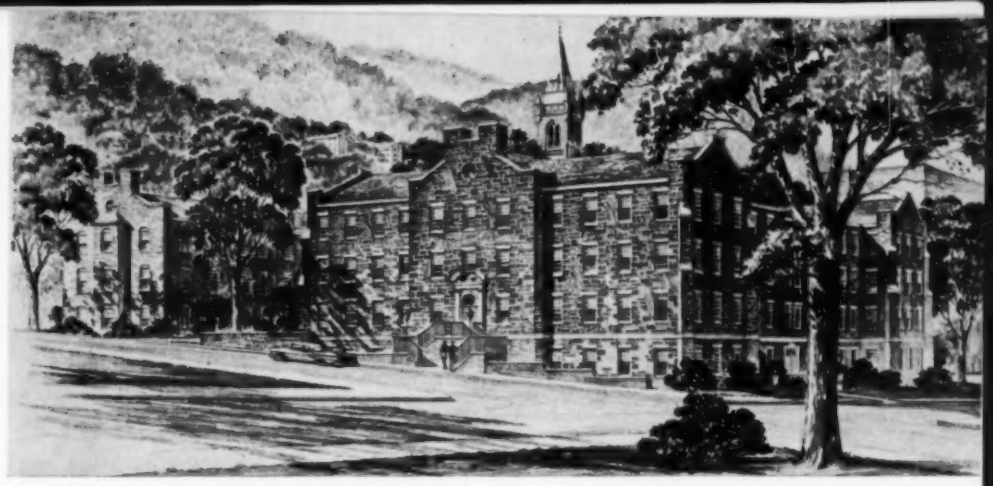
Early instruction, particularly in process metallurgy, tended to be descriptive in nature, the idea being that the metallurgical engineer had to be ready to step into industry and be capable of operating an existing process. However, the correct number of nuts and bolts on a copper converter is neither a challenging nor even an interesting discussion. Physical chemists opened our eyes to what was really fundamental about most of our metallurgical processes. Unfortunately, since then we may have embraced physical chemistry (particularly thermodynamics) so fervently that we neither noticed nor cared that inorganic chemistry can be a fascinating and useful subject. More recently the trend has been to incorporate what is called *the chemical engineering approach*, in which extractive processes for the multitude of metals in which we are interested are grouped together on a more fundamental basis, for example, in terms of the phases involved. This is perhaps the only correct approach. It involves analysis of processes in terms of their engineering and chemical fundamentals, with later integration.

The branching of curricula into two options, one concerned with process metallurgy, the other with physical metallurgy, is frowned upon in some quarters and encouraged in others. Yet, it may be inescapable if metallurgists are to hold their own with chemical engineers in the producing industries. Gradute instruction, at least to the M.S. level, is another possible solution to the difficulty, but advanced degrees in process metallurgy are not numerous enough at present. However, if we do not supply depth to our process education the chemical engineers may eventually engulf us. From the standpoint of survival we should be unwilling to see this happen, and as a matter of providing the correct man for the job, we should still be unwilling. The chemical engineers have somewhat neglected high temperature processes—with the exception of combustion—which are of principal concern to the process metallurgists, and they are certainly less well acquainted with the products of such processes.

This latter deficiency is an important one. One of the distinguishing characteristics of the process metallurgist is that he has an appreciation for and a knowledge of the structure and properties of his product. Such knowledge is essential, for example, in the operation of refining processes. In a similar fashion, the physical metallurgist is aware of the limitations of the material he uses because he knows something of the methods by which it is produced; few other engineers possess this type of training.

Depth vs breadth

The question of a broader versus a deeper education for the metallurgist is the same question that plagues educators in other engineering fields. The fact that the engineer exists for industry, not vice-versa, means that we tailor our students to the in-



Architect's sketch of the new Metallurgical and Chemical Engineering Laboratory, to be built on the campus of Lehigh University, Bethlehem, Pa.

dustrial demand. This does not mean that we abandon the right or privilege to decide how best to go about this, but whether or not the demand exists is something that industry and not the educator determines.

Iron and steel processes

It is easy enough to venture, in a somewhat general way, what will happen to the metal-producing industries in the future. In the steel industry, where demand for the product is unlikely to slacken in the foreseeable future, we should expect further development of existing processes and certainly the introduction of some new ones. There is nothing wrong with batch processes in principle, and we should not expect to see steelmaking suddenly take on all the aspects of a continuous operation. But there is room for a measure of continuity in the production of the common types of steel. It would not be especially difficult, given somewhat improved constructional materials—especially refractories—to adapt even the present integrated steel plant to semicontinuous operation through ore processing, smelting, refining by oxygen injection, deoxidation and alloying, and finally continuous casting and rolling to shapes. There will be further attempts to combine ore reduction and refining in existing furnaces, or development of direct steelmaking processes. These are not radical changes, but they involve economic and engineering problems. More automatic control and programming is inevitable. Vacuum processing will increase its impact, and there should be techniques to produce steels essentially free of inclusions.

Generally, for the cheaper steel with less critical applications, we should expect the main developments to be in the direction of cheaper and faster production techniques with more automatic control. In the higher-quality alloys, distinct improvements in quality will result from better deoxidation techniques, whether under vacuum or through the use, under pressure, of more powerful deoxidants such as calcium.

Nonferrous processes

In producing the more common nonferrous metals, such as copper, lead and zinc, the pattern may be similar, though it must be admitted that processing techniques in these industries do show considerable ingenuity at the present time. The same is true in the production of aluminum and magnesium, and, as with many of the other metals, eventually poorer raw materials than bauxite will be developed. The best source of supply is always exploited until it becomes economically feasible to turn to poorer sources. Only then is there a chance of ingenuity in the development of new concentration and refining techniques. It is likely that a combination of mineral engineering and pyrometallurgical techniques will be more fully exploited in the future. The US Bureau of Mines has, over the years, produced many examples of ingenious extraction methods of this type. As a general trend, it may be that the sequence of concentration, extraction, and refining will be modified somewhat, as it has been with titanium and other reactive metals, with more emphasis on the preparation of the pure compound before reduction to the metal.

Still more metals are likely to become commercially desirable, either for their properties in the pure form, as alloying additions, or as part of composite materials. Among them are many which are very reactive, such as the rare earth metals, so that halide reduction and electrolytic processes should be quite important. For other metals, the possibilities of carbon reduction have not been fully explored, particularly in conjunction with the use of rather low pressures, which were not available on a very large scale until recent years. In processes involving gases, it is likely that higher pressures will become more commonplace, since reactions of liquids and solids with gases are facilitated by operating at high pressures in which the gas molecule concentrations come a little nearer those of the liquid. This is a technique which has been used in the chemical industry, even when there is no direct advantage through displacement of the equilibrium. In general, the reduction techniques for the more reactive metals are not in an entirely satisfactory state, and the laborious batch processes will have to give way, to some extent, to steady-flow processes more typical of the chemical industry.

Refractories

There is great scope for development in refractories; this may well be the key to the introduction of higher processing temperatures. Many vacuum processes could be operated at much higher temperatures through the design of vessels in which the container, in the form of an outer shell, is kept

quite cool, while the interior reaction chamber is at a much higher temperature. The Simplex ferrochromium process is an example of such a process.

Much of the art which still remains in process metallurgy can be expected to disappear in the near future. The view that the processing history has an influence on the properties of the metal even though all possible concrete influences have been taken into account is still held in some quarters. There ought to be changes in the techniques available for solidification of metals which are produced initially in the liquid state; it is time we were able to control the direction and nature of crystal growth with a little more certainty.

New processes

Possibly the greatest challenge to the future process metallurgist lies in the development of essentially new processes, and it is here that his possible weaknesses, as compared to the inorganic chemist and the chemical engineer, may become apparent. Certainly in the scaling-up of new processes to production size, the chemical engineer seems to preserve a temporary advantage. Nevertheless, we may soon voice the same complaint as do many chemical engineering departments; we no longer teach sufficient chemistry—this should be done not for a detailed knowledge, but to develop an attitude of mind through association.

To outfit metallurgists for the process industry, education must keep pace with an expanding technology which will see the use of higher temperatures and higher and lower pressures in new extraction methods. It is not enough to be able to recognize a process on paper; it also has to be engineered. This does not imply that we have to equip our students to handle the last details of such processes. Although these processes may well involve considerable automatic control and programming, we should beware of falling into the obvious trap—computer operators are specialists, and it is sufficient for a metallurgical engineer to know only the rudiments of programming as the employer of such specialists. The present position of the analytical chemist in industry is a graphic example of this danger. Similarly, the engineer of the future need not be burdened by education in process economics. The dollar sign is somewhat stultifying to the creative engineering mind; he should respect the economists views, but not be intimidated by them.

We should be less concerned with the addition of new material in the education of the process metallurgist than with whether or not we have the correct approach to his present curriculum. It is said, with some justification, that present metallurgical education is lacking in any adequate treatment of process kinetics. Chemical engineering is always pointed to as the ideal we should attain. Coupled with this, however, is often the suggestion that we have gone far enough in thermodynamics. While this may be doubted, perhaps we have disposed of inorganic chemistry too lightly. These three areas are the key to the education of a metallurgist who can make his contribution in the process industry. In fact, it can be argued that they are the basis of of the training for almost any metallurgist. Although there are some larger questions to be considered, we should look to these three areas first of all.

Thermodynamics

In the first place, it is likely that process metallurgists have not been taught sufficient thermodynamics. In general, there have been two ways of attacking the problem, both of which involve first exposure to thermodynamics in the chemistry department, where the emphasis is on the chemical thermodynamics of low-temperature solutions. The second exposure often comes in the metallurgy department, and is either very much a thermodynamic calculation course or a stringent repetition of the first course, but with the examples chosen from systems of more interest to metallurgists. It is doubtful that either of these methods is sufficient. It might be preferable for the first exposure to deal almost exclusively with the principles of thermodynamics in a rather rigorous fashion with applications, by way of example, in all fields. The second exposure might recognize that metallurgists use thermodynamics as a tool. We should develop the same confidence in treating thermodynamics as we have in mathematics, where we recognize that early education in mathematics should be rigorous, but further education, especially of the engineer, should treat the subject primarily as a tool. This does not mean that the student is supplied with a list of formulae for particular situations, for this can never be called teaching, but at the same time there is no attempt to teach the engineer how to make excursions into the realm of pure mathematics. Our undergraduate metallurgists will use thermodynamics in their career as a tool and it is better that they should know the fundamental features of the tool and know well how to use it in a variety of situations.

Our process metallurgists know too little of the properties of solutions and the use of activity coefficients. Their knowledge of the phase rule and its applications is often less than rudimentary. To the engineering mind, it is by applications that the phase rule becomes clear and reveals itself as a possible tool in other situations. Rigid derivations are of less interest to the metallurgist than a clear knowledge of the exact conditions and limitations under which a particular thermodynamic expression may be applied. There is no easy solution to this problem of teaching thermodynamics.

Mechanical engineers not qualified

In some efforts to attract students into metallurgy, we may have gone too far in the direction of making it easier for mechanical engineers to swell our ranks and have forgotten that what we are dealing with is essentially applied chemistry. We should abandon this pretense, perhaps by reintroducing the name *chemical* metallurgy for that portion of our training. Most process metallurgists are lacking in knowledge of inorganic chemistry and, unless they have been exposed to the better methods of teaching mineral engineering, in knowledge of aqueous solutions. Pressure-leaching techniques are common knowledge to many chemists, but are imperfectly understood by most metallurgists. Since the abandonment of qualitative and quantitative analysis courses, metallurgists have too little appreciation for the chemical properties of the elements. Certainly metallurgists can make a fair list of the more common metals according to their oxygen pressures, but of their reactions with many other metals and non-metals (and especially reactions with organic materials) they know too little. It is ironic to note that broadening our curriculum in metallurgy to take account of other materials

would probably demand that this situation be corrected.

Teaching kinetics

In many ways, concern over our methods of teaching kinetics to process metallurgists is justified. Courses in classical chemical kinetics are less than useful —if anyone can find a homogeneous reaction of importance in metallurgy, this statement will be retracted. All our useful reactions are heterogeneous, in the sense that they take place by interaction between two phases, not by reaction of a homogeneous phase at a surface on which adsorption can take place. Here the chemical engineers have a significant advantage over us. Nevertheless, we should not make the mistake they are making in developing their own kinetic treatments. We should not go to a non-analytical approach to kinetics in which we are concerned with an overall process, using rate constants whose nature is poorly specified, but which give agreement with experiment. The method has utility, but we are not likely to make the progress that is required in kinetic treatment of processes with a strictly empirical technique.

One of our teaching problems in kinetics is that we tend to separate many very similar things. We teach heat flow, diffusion, and fluid flow; sometimes we take a unified view of these things, but more often we teach them as separate entities; this is obviously wrong. The processes of heat, mass, and momentum transfer are essentially similar in fluids, as are the processes of heat transmission by conduction and mass transport by diffusion in solids. If a student cannot immediately convert a solution in an unsteady-state problem in heat transfer to the similar case for mass transfer, he does not understand what he is doing. Nowhere is this deficiency more apparent than in the treatment of boundary layer theory, a much misunderstood subject: yet this theory is essential to an understanding of metallurgical process kinetics which must deal with many reactions involving fluids. We are hampered by a lack of adequate data and by the paucity of research on metallurgical systems, but we make inadequate use of what is available.

Materials engineering — a threat?

There is another question mark in our future. Solid state physicists have made us feel uncomfortable enough in our role as physical metallurgists that a demand for materials engineers brings further soul-searching and feverish activity. The trend in this direction will not be denied, and it seems to leave extractive metallurgy even further out in the cold. Material structure and properties occupy the largest part of proposed materials curricula, though it seems that for materials engineers some consideration of the processing of raw materials into useful objects cannot be left out. Nowhere is there consideration of the broader counterpart of process metallurgy.

Is our future home in such a situation to be in the arms of the chemical engineers? An argument, based on expediency, is that the process metallurgy field is too large to be so encompassed. Yet, if physical metallurgy develops into materials science and engineering our position seems to become illogical. Broadening our scope to include the preparation of other materials would seem to mean further overlap with chemical engineering, especially if we attempt to include polymers. The problem is largely one of a name. A department concerned with materials may be unbalanced if it teaches the structures, machines, and devices, yet includes only the extraction of metallic materials.

Chemical and metallurgical engineering

There is no obvious and easy solution to this problem, partly because the manner in which materials may be introduced to present undergraduate metallurgy curricula is not by any means clear. Where there is already close cooperation between departments of chemical and metallurgical engineering, the problem would seem less serious; to some extent the talents of both departments are already combined. Perhaps the most desirable solution is that such combinations should become even stronger in the future. Where such situations exist, there is an ideal opportunity for development in the direction of broadening the interests of both metallurgists and chemical engineers. There would have to be sufficient elective time to allow a student to bridge the gap that presently seems to exist between chemical engineering and metallurgy. I believe that such integrated departments could make great contributions in both fields.

In other cases, it is unlikely that such a combination can ever be developed. Many metallurgy departments pay only lip-service to processing or extraction; nor is it desirable that there should be conformity in every metallurgy department in the country. It seems that the strengths of many departments lie in the fact that they are noted for specialization in one aspect or another of metallurgy. Their size is such that any attempt to cover the entire field would only result in dilution, to the great detriment of the departments.

There are other, larger departments of metallurgy whose students are in demand by both metal producing industries and the larger number of utilization industries. For such departments, the broadening of interests to include other materials poses the particular problem that their process-inclined engineers may no longer look so desirable to the metals industry. In the foreseeable future, such departments should not abandon the attempt to turn out a suitable process metallurgist by delegation of such responsibilities to chemical engineering. However, we have to convince the process industries that we have something to offer, and this will only come about through a greater concentration on chemisty, useful thermodynamics, and especially process kinetics. Perhaps our saving grace will be in the recognition that graduate process metallurgists are a very desirable product. Some of the luster that present graduates shed will certainly be reflected to the undergraduates trained along similar lines.

This is suspiciously like a policy of laissez faire. Its end result should see the employment of more and more chemical engineers working together with process metallurgists in the metals-producing industries. While such combinations are good, they do mean that growth in process metallurgy training may be somewhat curtailed in the future. What we have to avoid, and what we can avoid by slight modifications in our present training and by way of example from our good students, is the feeling that the chemical engineers are preferable to process metallurgists, rather than a complement to their efforts.

Materials engineering
Metallurgical education

INDUSTRY'S VIEWPOINT ON TRAINING IN METALLURGY AND MATERIALS

A competent engineer, grounded in fundamentals, who is a professional man in every sense of the word is the type of graduate that is here specified.

by George A. Roberts

INDUSTRY—by which is here meant the metal-working industry, and which has been estimated to represent, in its broadest sense, 40 pct of our total economy—does three things: it *buys*, it *makes*, and it *sells*. Since it also buys the product of the engineering schools, it is possible to approach this subject as if one were writing a specification—one for the graduate engineer. In this specification, the qualities that industry wants and expects should be listed. Yet, there are naturally variables depending upon the job to be done.

A qualification is necessary here. *Metallurgy* and *materials* are words currently employed in a semantic and pedagogical battle among educators and some industrial engineering leaders. It is not necessary here to get involved in this discussion; the principles of concern should be applicable whether we train broad wood-plastic-ceramic-metallurgists, metallurgical physicists, solid state engineers, or indeed, any kind of engineer.

It is obvious that there is no one person who is qualified to speak for all of the metal-working industry as it has been defined. The writer's experience has been in the steel industry, and perhaps more important, with a small company. The problems of such a small enterprise, where professional employees may number under 30, the needs for greater breadth and vision per individual, and the needs for stability in the professional force, all of these factors may play a greater role here than they would in the views of someone differently situated.

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Industry functions

The variables in our specification will depend first on the type of industry doing the purchasing.

Metallurgical graduates are employed in relatively large numbers by the electrical, metalworking, automobile, oil, chemical, and research industries. They are also absorbed in significant percentages by the government and the universities themselves; in the latter case, a form of interplant sale or transaction for which specifications should be, perhaps, written stringently by the educators themselves.

The steel industry, for example, employs the product in many functions and is not limited in its purchasing search to any one type of individual, or to any one final opportunity for him. The subject content of the specification may vary geographically; none of these variations, however, affect the substance of the specification which is of concern here.

The aforementioned industrial formula of buying, making, and selling carries over to the universities themselves. By encouraging enrollment, screening candidates, and admitting students they perform the buying function; training them for a finite

number of years constitutes the making function; while the selling function is effected through placement activities, organized or unorganized.

All three of these central functions also become involved in the attitudes of industry toward the product. Big corporations may differ considerably from small companies in this regard, where separation of the three is not only more easily accomplished, but, in fact, desirable and mandatory for efficiency of employment of the graduate. Here specialization in course content, in knowledge acquired, and in attitudes of work can be tolerated, whereas they may not be desirable in the small manufacturing unit.

Regardless of size, however, these are the things we find metallurgical engineers doing after they leave college:

- Research
- Development
- Process Planning
- Sales
  - Direct
  - Sales Engineering
- Technical Services
  - Related to Selling:
    - Customer Service
    - Laboratory Operation
    - Consultation and Advice
    - Writing
  - Related to Buying:
    - Specifications
    - Process Control
    - Inspection
- Administration—

  effectively applicable to all of the above items.

Among several of these, the level of training, required intelligence, and pay may differ. But, at the undergraduate level this observer does not believe a different level, type, or degree of curriculum is required. Broad specialization will be inevitable from university to university, from professor to professor, from district to district, but early and detailed specialization could easily, and perhaps, should be avoided.

Training in industry

Industry expects to do a certain amount of training in the details of its peculiar technology. Too often it seems an undergraduate curriculum deals so much with the items of training more suited to the level of technicians than to the professional man. While it is a truism that the doing is most of the learning, that to instruct, teach, or train, or supervise later in life, the graduate should have done with his own hands or brain the things technicians are so readily available to perform, there is distinct limit to the extent this training is needed. While learning to do, he should have learned to create thoughts or ideas surrounding his new medium, machine, or tool; to appreciate the creativeness inherent in the science brought to that point for him by his predecessors. In one broad grasp—one large image—he should see the past, the *raison d'etre*, the present, the use and at least the curtain to the future. He will sooner or later peer through, or around it.

Research and development are not alone in this sense. None of the listed activities can be done well without a curious mind, a creative urge. This need exists in sales, in control, in service, as in research. We have quite enough drones in the industry—yes, and metallurgical ones.

Status of technicians

Technicians are truly a factor to be reckoned with. During the recent years of searching for reasons why more metallurgical graduates were not available, and in fact, why engineers in all categories were in short supply, many companies discovered the technician as a means of increasing the efficiency and output of their core of engineering personnel. They found that technicians are available, trainable, and talented. They found many young high school graduates who, with modest training, could perform services even beyond some of their professional staff. Such a consideration should be uppermost in the mind of engineering educators, who must see that their product is better than the industry can make in its narrow self-interest. The schools must sell a superior product whose usefulness is unquestioned and whose advantages are self-evident.

Professional training

To have a professional man, the university must teach him such that he is never to be mistaken as a mechanic or a technician (the reverse is far from the truth). How can this be always accomplished? As is obvious, by training him soundly in the basic fundamentals of his chosen field.

This does not mean all theory. Facts, data and perspective are fundamentals. Chemistry, physics, and mathematics are fundamentals. Phenomena, too, can be fundamental. The inter-relation of facts, or of phenomena are fundamentals of importance. For a metallurgist, these fundamentals *need* to be taught about metals and materials. Industry wants men so trained.

Industry also looks for the man. The schools are ready to sell their product, industry to buy. The article is too often not ready for sale as a man: insecure, fumbling, groping with no sense of the world in which he will step or will mark or will run someday; no understanding of the makeup of the industrial world which beckons him. Such shortcomings are not universal, yet it seems to be a statistical function of the school from which he is produced. Why? This is a tough question, but it can be avoided or corrected by modern courses which touch on the world outside *as it is*, not as it is dreamed to be by professor or industrialist.

Industry looks constantly for leaders, for creativeness, for men capable of independent action. It looks for rationality, for a method of scientific approach to all problems. It wants an ability to evaluate problems, or perhaps, even more important, an ability to evaluate answers. It wants men who can communicate. It wants men who can intermingle.

Industry wants men who can appreciate our culture and our heritage. It wants men to be politically aware, to be community minded, to be professionally inspired.

Is this a sufficiently difficult specification? In fact, it is supposed to be. And it is safe to say that industry will always provide a ready market for such a product.

Phases and Processes

HIGHLIGHTING CURRENT DEVELOPMENTS IN METALS

Semiconductor Metallurgy

by J. H. Wernick,
Bell Telephone Laboratories

EMPHASIS on research and applications of semiconducting compounds was evidenced at the Conference on Properties of Elemental and Compound Semiconductors, sponsored by the IMD Semiconductors Committee of The Metallurgical Society, in Boston August 31st to Sept. 2nd. The Conference was successful, as attested by the quality of the papers presented and the fact that the attendance was 490. Highlights of the papers are presented below.

Stoichiometry in Compound Semiconductors was discussed by W. W. Scanlon of the Naval Ordnance Laboratory. Most compounds exhibit deviations from ideal stoichiometry, resulting in electron or hole conductivity type, depending on the nature of the deviations. Equilibrium equations, involving vacancies and anions and cations in the solid and vapor states, can be written and analyzed.

Materials Research on GaAs and InP for High-Temperature Transistors was discussed by L. Weisberg and F. D. Rosi of RCA. These Group 3 - Group 5 compounds have relatively high energy gaps and electron mobilities and, therefore, are potentially useful for high-temperature devices. The materials research encompasses the preparation of single crystals of high purity and their subsequent evaluation by means of electrical measurements. Purification procedures and single crystal growing techniques were discussed. The electrical behavior of a number of impurity elements was also presented. Minority carrier lifetimes of 0.1-0.3 μ sec in GaAs were reported. J. M. Whelan, J. D. Struthers and J. A. Ditzenberger of Bell Telephone Laboratories presented distribution coefficients for Si, Ge, Cu, and Fe in GaAs. Upper and lower limits for the distribution coefficients of the volatile impurities S, Se, Te, and Zn were also presented. As the compound semiconductors become increasingly important, this kind of physio-chemical information is needed for controlled technological processess.

R. Davis of Westinghouse discussed the *Properties of SiC and GaP for Power Rectification*. GaP appears to be suitable for operating temperatures of the order of 400°C and perhaps higher. The purity and crystal perfection problems for these materials are still present.

Materials for Thermoelectric Applications, such as Bi_2Te_3-Bi_2Se_3-Sb_2Te_3 solid solutions, InAs-InP solid solutions, and GeTe, were discussed by R. W. Ure, Jr., R. Bowers, and R. C. Miller of Westinghouse. GeTe appears to be a useful material at elevated temperatures (500°C and higher) for power generation. Along this same line, S. E. Mayer and A. I. Mlavsky of Transitron discussed the *Electrical and Thermal Properties of Some Silicides;* for example, chromium and magnesium silicides. Similarly, the properties of InAs-GaAs solid solutions in regard to power generation were discussed by M. S. Abrahams, R. Braunstein and F. D. Rosi of RCA. Energy gaps as a function of composition were presented. These solid solutions appear promising for this application. C. Kolm and J. J. Giacalone of MIT Lincoln Laboratory discussed the *Thermoelectric Properties of Pressed Bi_2Te_3 Powders*. Since cast Bi_2Te_3 specimens are mechanically weak due to pronounced (111) cleavage, pressed and sintered elements appear attractive. However, much work needs to be done in order to bring the properties of specimens made by this method to the level of cast specimens.

The detrimental and beneficial effects of oxygen in Si were the subject of one session. The electrical effects and heat treatment behavior of oxygen dissolved in Si were reviewed by H. Reiss and W. Kaiser of Bell Telephone Laboratories, and a kinetic model which appears to explain the experimental observations of the donor behavior was presented. There is strong evidence that oxygen is an interstitial impurity in Si. On the other hand, M. M. Atalla of Bell Telephone Laboratories discussed the preparation of SiO_2 films on Si and the important possibility that these films may be useful for protecting devices from detrimental ambients. He also pointed out that these films can be used to create *p-n* junctions very near the surface of silicon doped with acceptor and donor impurities. The creation of the *p-n* junction will depend on the diffusion coefficients and the distribution coefficients of impurities between semiconductors and oxide film. C. D. Thurmond of Bell Telephone Laboratories estimated the equilibrium distribution coefficients of impurities between semiconductors and oxide film by making use of the free energies of formation of the impurity oxides. Atalla further pointed out that the mechanism of oxidation of Si is being investigated.

Dislocations in Semiconductors were discussed by W. C. Dash of General Electric. With special emphasis on Si, he pointed out that a crystal, initially free of dislocations, subjected to slight surface damage, and subsequently heated, will contain a large number of dislocations. This is an important consideration in device fabrication. It was suggested that the spiral pits observed on (111) Si surfaces are not associated with dislocations. The panel discussion concerned with *The Role of Dislocations in Device Properties* produced many comments from the conferees. Dislocations in GaAs, as revealed by etch pits, were discussed by M. S. Abrahams and L. Ekstrom of RCA. Dilute HNO_3 acid is suitable for revealing dislocations as etch pits only on the (111) plane.

A powerful but presently rather expensive tool for analysis of semiconductor alloys was discussed by J. M. Axelrod and D. B. Wittry of Hughes Aircraft Co. It is known as the Electron Probe X-ray Micro-Analyzer and has rather general application. It makes use of the fact that when a small area of specimen is irradiated with electrons, X-rays are emitted. Local differences in composition can therefore be detected.

Another item receiving considerable attention is the Esaki or tunnel diode, as evidenced by the increasing number of technical publications on the subject. However, no work pertaining to this item was discussed at the Boston meeting. The quantum mechanical tunneling of electrons was first observed by Dr. Leo Esaki in Ge diodes doped to degeneracy ($\sim 10^{20}$ carriers per cc). Diodes of this sort have considerable practical applications. The metallurgical effort associated with this product involves the preparation of uniform highly-doped semiconductors (near saturation for some impurity elements).

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Since there is now no question that the building will be erected, the drive for funds cannot be allowed to slow down. This message reaches you at a time when the societies have just passed the three-quarter mark in our fund campaign. The home stretch — and victory in this united drive — lie in the weeks ahead.

Now is the time for all campaign workers to make sure that all members of each section have at least been approached. It is the time for all sections of all societies to strive for 100 per cent completion of their quotas. It is the time for those sections which already have reached their money goals to keep trying for contributions from as near 100 per cent of their members as possible.

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AIME NEWS

Semiconductors Conf. Draws 490

An attendance of 490—far exceeding expectations—is one indication of the success enjoyed by the Semiconductors Committee of The Metallurgical Society's Institute of Metals Division in staging its first technical conference. Registrants attended two days of technical sessions at the Statler-Hilton Hotel in Boston on Aug. 31st and Sept. 1st. And, almost one-third of them stayed around to visit the Solid State Materials section of Massachusetts Institute of Technology's Lincoln Laboratory the morning of Sept. 2nd.

The technical sessions were generally concerned with metallurgical aspects of elemental and compound semiconductors. Lively discussion indicated that the program organized by the Committee held great interest for registrants, who represented universities and government research activities, as well as a wide variety of electronics companies.

Non-technical activities of the conference were limited to a social hour and fellowship dinner on Monday evening, Aug. 31st. Toastmaster T. B. King of MIT, Chairman of the co-sponsoring Boston section of AIME, prepared the 130 persons attending the dinner for a well-received talk by Prof. Patrick D. Wall, also of MIT. Prof. Wall's topic was *Sensation and Nervous System.* After describing the basic mechanism for transmission of nerve impulses in living organisms, Prof. Wall described the ingenious ways in which the nervous systems of various animals have adapted to their specific situations.

In view of the success of this Fall's conference, the Semiconductors Committee will give serious consideration to the possibility of holding another meeting in approximately one year. Tentative plans for a 1961 conference on the West Coast had already been formulated at the time of this year's meeting, and it is expected that such a meeting will still be held.

INTERSCIENCE TO PUBLISH METALLURGICAL SOCIETY CONFERENCE PROCEEDINGS

The Metallurgical Society has concluded an agreement with Interscience Publishers, Inc., to publish a new series of books, entitled METALLURGICAL SOCIETY CONFERENCES. With the appearance of the first of these volumes, a new and important phase in the publishing program of the Society has begun. Each volume of the series will be the proceedings of a technical conference sponsored by the Society or one of its technical committees.

Flat Rolled Products: Rolling and Treatment is the title of the first of the series. The volume is just off the press, and is priced at $3.75. AIME members may purchase their copies at a 20 pct discount for $3. Registrants at the Jan. 21, 1959, Chicago Technical Conference from which these proceedings were taken will automatically receive a copy of the book as part of their registration fee.

John Chipman, President of The Metallurgical Society has this to say in his Introduction to the Series: "This volume on **Flat Rolled Products: Rolling and Treatment** marks the first of a series of books that will cover the spectrum of metallurgy. Here is an exciting new means for disseminating technical information widely, and in a coordinated and up-to-date fashion . . .

"While books in the series will vary in composition, printing methods, and binding, the format will be uniform. The aim is to publish a book of high quality at the lowest possible selling price consistent with the probable demand for the book."

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Members of the AIME may order this and succeeding volumes through The Metallurgical Society, 29 W. 39th St., New York 18, N. Y., and receive a 20 pct discount on the original price. Non-members may obtain volumes of the series by ordering directly from Interscience Publishers, Inc., 250 Fifth Ave., New York 1, N. Y.

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FUELS AND FUEL ELEMENTS SUBJCET OF *Nuclear Metallurgy (Vol. VI)*

"The Effects of Irradiation on Fuel and Fuel Elements" is the subject matter of **Nuclear Metallurgy (Vol. VI)**, the proceedings of the Nuclear Metallurgy Symposium at this year's Fall Meeting. The 11 papers which comprise this volume will be presented at the Nuclear Metallurgy Committee's all-day symposium Wednesday, Nov. 4th.

W. D. Manley, Symposium chairman, outlines the scope of the book in its foreword: "This symposium will discuss the present status of the irradiation behavior of the various fuel element materials and the progress that is being made in the understanding of the limitations of the present fuel element designs," he explains.

"The symposium is divided into two sections: 1) The behavior of metallic fuel materials; and 2) The behavior of the ceramic fuel materials.

"The first part of the session will discuss the fundamentals of fission damage and explains phenomena such as growth, swelling, and radiation-induced phase transformations that limit the useful life of metallic fuels. This will be followed by papers discussing the irradiation behavior of engineering materials.

"The second part of the session will discuss the behavior of ceramic fuel materials. The best examples of this class of fuels are uranium oxide and uranium carbide. Since the long-range potential of the nuclear technology depends upon breeding new fuel, papers are presented on mixed fuel materials such as plutonium oxide-uranium oxide and thorium oxide-uranium oxide. The radiation behavior or uranium-fissium and uranium-plutonium-fissium fuels for fast breeder reactors will be discussed."

Copies may be purchased at the Registration Desk in the Morrison Hotel during the Fall Meeting. After Nov. 5th, mail orders will be accepted through The Metallurgical Society, 29 W. 39th St., New York 18, N. Y. The list price of Vol. VI is $7, however, AIME members may obtain it for the special price of $5. The five preceding volumes of Nuclear Metallurgy Symposium Proceedings are also available, either at the Meeting or by mail.

Nuclear Meeting Set for Nov. 4-6

The American Nuclear Society will stage its Winter Meeting in Washington, D. C., Nov. 4-6. Headquarters for the Meeting will be the Sheraton Park Hotel there. More than 200 technical papers will be presented at the Meeting, to be attended by over 1100 men in atomic energy.

Reprocessing of Nuclear Fuels to be Discussed

A two-day symposium on the reprocessing of nuclear fuels will take place in Richland, Wash., Oct. 20-21. Sponsored by the US Atomic Energy Commission and a number of AEC contractors, the symposium will review the technology currently available for reprocessing spent fuels from research, test, and power reactors. Mechanical handling methods, chemical processes, materials of construction for processing equipment, and specific site plans will be presented and discussed.

Those management and technical personnel wishing to attend may obtain details from program coordinator *J. T. Christy, Hanford Operations Office, US Atomic Energy Commission, Richland, Wash.*

Hudson-Mohawk Section Plans Columbium Symposium for June, 1960

A symposium on the metallurgy of the metal columbium is in planning by the Hudson-Mohawk section of AIME. The Columbium Metallurgy Symposium is scheduled for June 9-10, 1960, at the Hotel Sagamore, Bolton Landing, Lake George, N. Y.

A relaxed atmosphere is assured for the conference, a far cry from the usual big-city gatherings. Also noteworthy is the fact that a fledgling Section (only in its second year of organization) is sponsoring this major conference.

Technical sessions are planned for both days, with papers on the mechanical properties, fabrication, corrosion and oxidation, and the general physical metallurgy of columbium. The Lake George setting will also provide the backdrop for an evening panel discussion June 9th, preceded by a cocktail hour and banquet.

Dr. David L. Douglass, Symposium Committee Chairman, is accepting abstracts of papers for presentation. They should be in his hands by Feb. 1, 1960. Address the abstracts to *Dr. D. L. Douglass, Knolls Atomic Power Laboratory, General Electric Co., Schenectady, N. Y.*

P. G. SHEWMON

Paul G. Shewmon Wins Alfred Noble Prize for 1959

AIME member Paul G. Shewmon, asst. prof. of metallurgy, Carnegie Institute of Technology, has been awarded the Alfred Noble Prize for 1959. The award is annually granted to a member of the AIME, ASCE, ASME, AIEE, or WSE under 30 years of age who publishes a paper in one of the respective societies' publications which is adjudged most outstanding by the Prize Committee.

Published in the October 1958 TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME, the paper was entitled *The Redistribution of a Second Phase During Annealing in a Temperature Gradient.*

C. L. McCabe Heads Metallurgy Dept. at Carnegie Tech

Charles L. McCabe has replaced Robert F. Mehl as head of the Dept. of Metallurgical Engineering at Carnegie Institute of Technology. Dr. Mehl relinquished the post in order to devote more time to research.

As the new dept head, Dr. McCabe brings with him a history of AIME activities in addition to his professional accomplishments. He is currently a member of the Extractive Metallurgy Division's Executive Committee, and is past chairman of the Pittsburgh section.

Primarily concerned with the physical chemistry of steelmaking and high temperature thermodynamics and kinetics, Dr. McCabe is the author or co-author of 15 scholarly publications.

AGGLOMERATION SYMPOSIUM TO FOLLOW NOHC - BLAST FURNACE MEETING IN 1961

An International Symposium on Agglomeration will be held in the US under the joint sponsorship of The Metallurgical Society and the Society of Mining Engineers. The meeting is scheduled for Apr. 12-14, 1961, at the Sheraton Hotel in Philadelphia. The conference will immediately follow the 1961 Conference of the National Open Hearth Steel Committee and the Blast Furnace, Coke Oven, and Raw Materials Committee in Philadelphia at the Sheraton Hotel, Apr. 10-12, 1961.

The joint sponsorship of the meeting results from a common interest in agglomeration shared with the Society of Mining Engineers, and in particular its Minerals Beneficiation and Industrial Minerals Divisions.

Both Societies felt that a 1960 date would not allow adequate time for conference planning, so it was decided to schedule it for 1961. For the convenience of the many steel men who are concerned with sintering and related problems, the agglomeration conference is scheduled immediately after the Blast Furnace and Open Hearth Conference so that registrants can remain in Philadelphia and take in the Symposium as well.

The meeting will not be limited to studies of sintering and pelletizing ore, however. A direct appeal will be made to those concerned with sintering of lead, zinc, and copper ores. The symposium will also encompass the agglomeration of nonmetallics, industrial minerals, and carbonaceous materials. Consideration will also be extended powder metallurgy aspects of agglomeration, both ferrous and nonferrous.

As to approach, basic process mechanisms common to agglomeration processes in general will be considered. Thus, the meeting will be more theoretical than applied. Detailed descriptions of operations will be included only if a specific purpose is to be served. The program will be comprehensive, beginning with size distribution of materials to be agglomerated and concluding with the utilization of agglomerated products.

General Chairman for the International Symposium will be W. B. Stephenson, affiliated with the Minerals Beneficiation div. of the Society of Mining Engineers. D. C. Brown of the Iron and Steel Division's Blast Furnace, Coke Oven, and Raw Materials Committee is Chairman of the Technical Program Committee.

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Main objectives of the studies are to evaluate the chemical, physical, and mechanical properties of metals and ceramics, and to study the effect of external conditions of stress, temperature, and strain rate on the materials, as well as the effect of alloy additions, impurities and past strain histories.

Preliminary studies are also being made in: transpiration-cooled and heat-resistant rocket nozzle material systems; thermionic-emission converter materials; solid-state devices for electronic application; electro-chemical fuel cell systems; substrates and films for the micro-miniaturization of electronic systems; analysis of fuel and oxidizer tank leakage problems; and materials development for nuclear propulsion reactors.

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Fall Meeting Nears!

Herbert Friedman, superintendent of the Atmosphere and Astrophysics div. of the Naval Research Laboratory, has agreed to speak at the Annual Dinner during the Fall Meeting, the evening of Nov. 3rd. The Dinner is being sponsored by the Institute of Metals Division. Dr. Friedman's subject will be *The New Astronomy*, which will deal with studies of outer space through use of rocket probes.

A total of 16 technical sessions, based on over 140 papers are scheduled at this year's Fall Meeting of The Metallurgical Society, Nov. 2-5, at the Morrison Hotel in Chicago.

Each of the Society's three Divisions will run simultaneous meetings both mornings and afternoons, Monday through Thursday.

The Institute of Metals Division's Committee on the Chemistry and Physics of Metals is sponsoring two symposiums: Kinetics of Phase Transformations on Monday morning; and Mechanical Properties of Non-Metals on Tuesday morning.

The Iron and Steel Division will present a program on the Recent Advances in Steelmaking the morning and afternoon of Tuesday, Nov. 3rd.

The Extractive Metallurgy Division's High Temperature Materials Committee is co-sponsoring a Symposium on Preparation, Purification, and Properties of Refractory Metals with the IMD Refractory Metals Committee.

Also on the calendar is the Eighth Annual Titanium Symposium under the auspices of the IMD Titanium Committee, scheduled for Tuesday morning and afternoon. The Division's Nuclear Metallurgy symposium will also be on Tuesday.

The EMD Committee on the Physical Chemistry of Extractive Metallurgy has also reserved Tuesday afternoon for a symposium on Refining of Pure Metals.

Then, on Wednesday, the IMD Nuclear Metallurgy Committee will present its annual symposium, this year on the subject of Effects of Irradiation on Fuel and Fuel elements. Thursday will witness the IMD's symposium on powder metallurgy. The Non-Ferrous Metallurgy Committee of the IMD will also hold its symposium on Current Practices in the Melting and Casting of Non-Ferrous Metals on Thursday.

A total of 16 other sessions, based on the submission of research abstracts, are also scheduled for the Fall Meeting.

Registration for the Meeting will begin at 3 p.m., Sunday, Nov. 1st, on the Morrison Hotel's first floor foyer. Members are urged to register in advance, if at all possible. The registration fee of $5 to AIME members and $10 to non-members entitles them to an abstract booklet, as long as the supply lasts. Student members will be admitted free, while non-member students must pay a $1 fee.

Powder Metallurgists to Probe Surface Films at Fall Meet

The little-understood role of metal oxides on the surfaces of metal powders will come under close scrutiny when the Powder Metallurgy Committee presents its part of the program at the Fall Meeting of The Metallurgical Society.

During its two-session, all-day Symposium Nov. 5th the Committee will try to unravel the mystery of why surface films sometimes limit sintering, while at other times facilitate the process. "As applications of powder metallurgy become more diverse and as new alloys are sought for high strength, high temperature uses, surface oxide films often constitute a major technological barrier to progress," explains G. L. Bibbins, Powder Metallurgy Committee Chairman. "It is to gain a closer insight into this critical problem that the symposium has been organized, drawing on the experience of outstanding researchers from the US and France."

These and other sessions are in store for those who attend the Fall Meeting, Nov. 2-5 at the Hotel Morrison, Chicago.

Relationship Between Metals, Non-Metals to be Aired

The inter-relationship between metals and non-metals will be borne out during the Chemistry and Physics of Metals Committee's symposia at the Fall Meeting. Part of the Institute of Metals Division's programming, technical meetings will involve papers on plastics and ceramics, in addition to metals.

Richard S. Davis, Arthur D. Little, Inc., who will preside at the Tuesday morning, Nov. 3rd session, explains it this way:

"Ideas and techniques developed by metallurgists are useful in discovering and developing new plastics and ceramics. Also, basic knowledge about how non-metals behave helps metallurgists to a better understanding of the behavior of metals. Every day, the practicing metallurgist must solve problems involving non-metals."

Four sessions are scheduled altogether for the mornings and afternoons of Nov. 2nd and 3rd. Afternoons will be devoted to summaries of current research in fields covered by papers in the morning sessions. See the Fall Meeting Program in the September issue for the listing of papers to be presented.

SENIOR AND JUNIOR METALLURGISTS: To plan, direct, carry out materials research and development in the nuclear field. Opportunities exist for both applied and basic work in a new laboratory. Currently in progress are programs in thermal stress fatigue, alloy development, high temperature properties, fuel element development, ceramic coating techniques and properties. An advanced degree and/or experience in the nuclear field would be desirable. Send resume to Dean W. Townsend, Advanced Technology Laboratories, Division of American-Standard, 369 Whisman Road, Mountain View, California.

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Contract Research for Industry and Government

Flat Rolled Products Meeting Program Now Taking Shape

The program for the second conference on Flat Rolled Products, to be held Jan. 20, 1960, is rounding into final form. Sponsored by the Mechanical Working Committee of the Iron and Steel Division, of The Metallurgical Society, AIME, the conference will meet at the Del Prado Hotel in Chicago.

Though still tentative, the agenda calls for papers and discussions on *Hot Machine Scarfing . . . Selection of Ingots and Slab Sizes . . . Scaling . . . Stretcher Strain Sensitivity . . . Corrosion and Fabrication Problems of Unitized Car Body Construction* . . . and *Processing of Steels for Electrical Applications.* Selection of the luncheon speaker is yet to be announced.

Analytical Symposium to Meet in New York

The First Eastern Analytical Symposium, sponsored by the American Chemical Society, Society for Applied Spectroscopy, and the Metropolitan Microchemical Society, will be headquartered at the Hotel New Yorker, Nov. 4-6.

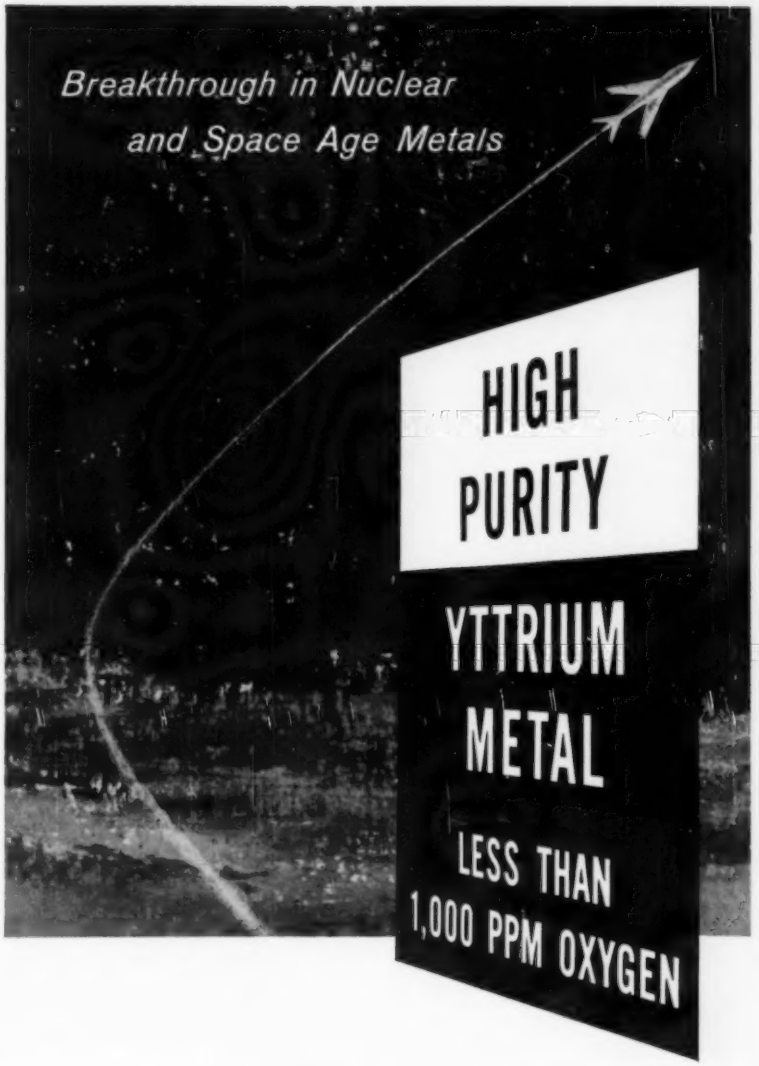
Composed of a series of three-hour symposia, the meeting will take up such subjects as Infrared Spectroscopy . . . Voltammetry . . . Masking in Analytical Chemistry . . . Non-Routine Sampling . . . Mass Spectrometry . . . Spectrophotometry . . . Emission Spectroscopy . . . Ion-Exchange . . . Organic Analysis . . . X-ray Spectroscopy . . . Thermal Methods of Analysis . . . and Microtitrations.

Registration fee is $3. For more information, contact: *Charles Jedlicka, Lucius Pitkin Inc., 47 Fulton St., New York, N. Y.*

Diffraction Conf. at Pittsburgh Nov. 11-13

The 17th Annual Pittsburgh Diffraction Conference will be held at the Mellon Institute, Nov. 11-13. Sessions on stress analysis, refractories and silicates, and biological structures will highlight the two-day meeting, while a symposium on electron microprobe analysis is also on the agenda. Another focal point of the meeting will be an address by AIME member Dr. Charles S. Barrett, of the University of Chicago.

For further details, contact: *D. W. Beard, Crucible Steel Co. of America, 234 Atwood St., Pittsburgh 13, Pa.*



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IMD Lists Selections for Society Nominating Committee

The Institute of Metals Division has nominated the following men to serve on the Nominating Committee of The Metallurgical Society for a one-year term beginning February, 1960: Morris Cohen, Massachusetts Institute of Technology; Walter A. Dean, Aluminum Co. of America; and Oscar T. Marzke, U. S. Steel Corp. Nominees from the other two Divisions were listed on page 471 of the July JOURNAL OF METALS.

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New opportunities in the growing and important field of refractory metals are now available with du Pont at the Experimental Station in Wilmington, Delaware. A major expansion in alloy development, metal manufacture and mill product processing techniques is being conducted. Trained Ph.D. research personnel in physical and mechanical metallurgy, or those with equivalent research experience, are needed to support this program. These positions offer an opportunity for direct contribution to the development of niobium base alloys and titanium base alloys as well as additional refractory base systems. Please forward resumé including details of education, experience and salary expected to Mr. Harry Joslyn, Employee Relations Department, E. I. du Pont de Nemours & Company, Wilmington, Delaware. Replies held confidential.

AROUND THE SECTIONS

Connecticut section will hear Dr. James H. Bechtold of the Westinghouse Corp. speak on Materials Engineering at its Nov. 12th meeting. The get-together will be held at the Chase Country Club, outside Waterbury. The meeting has also been proclaimed President's Night, and AIME President-Elect Joseph L. Gillson will be among the guests.

Detroit section's opening meeting for the 1959-1960 season on Oct. 19th will feature a talk on *Electron Probe Microanalyzer*, by Dr. Kenneth G. Carroll, supv. of Metal Physics Research Section, International Nickel Co., Inc. Meeting place, as always, will be the Rackham Memorial Building.

Washington, D. C. section held its first meeting of the season Oct. 6th at the Broadmoor Hotel. Highlight of the dinner meeting was a talk entitled *Operation Plowshare*, by Richard Hamburger, of the Division of Military Application, US Atomic Energy Commission.

Lehigh Valley section donned boots and hard hats Sept. 19th for a field trip through the mine and surface plant of New Jersey Zinc Co. at Friedensville, Pa.

Set Basic Oxygen Meeting for Oct. 14

The Acid Converter and Basic Oxygen Steel Committee of The Metallurgical Society, AIME, will meet at the Algoma Steel Corp., Ltd., Sault Ste. Marie, Ontario, Canada, on Oct. 14th. The day will start with a plant visit at 9:00 am, to be followed by a luncheon and an "off-the-record" meeting of committee members and guests. The technical portion of the meeting will be devoted to operating problems encountered in the production of basic oxygen steel and acid bessemer steel, advises Arthur B. Wilder, Committee chairman. For further information, contact Mr. Wilder at the: *National Tube Division, U. S. Steel Corp., 525 William Penn Place, Pittsburgh.*

Committee plans also call for an all-day session on oxygen steelmaking during the Iron and Steel Division's portion of the Annual Meeting next February. A number of technical papers, accompanied by open discussions, will be presented. Details will be found in the 1960 Annual Meeting program.

EMD Schedules International Type Symposium for 1960

The Extractive Metallurgy Division has scheduled an International Symposium on the Extractive Metallurgy of Copper, Nickel, and Cobalt as part of its contribution to the 1960 Annual Meeting.

Broad in scope and jointly sponsored by four EMD Committees, the program will cover the following subjects: roasting . . . fuel-fired smelting . . . electric smelting . . . converting . . . atmospheric-pressure leaching . . . elevated-pressure leaching . . . copper refining . . . nickel refining . . . and cobalt refining. Papers will be presented by scientists from Belgium, Canada, Chile, France, Germany, Northern Rhodesia, Norway, and Sweden, as well as the US. Papers may also be forthcoming from Soviet sources, according to Paul Queneau, Chairman of the Symposium.

M. A. HUNTER

Die Casters Award Bestowed on Hunter

Matthew A. Hunter, Dean Emeritus of Rensselaer Polytechnic Institute, has been awarded the American Die Casting Institute's Doehler Award for 1959. Now a consultant to the Die Casting Research Foundation, Dr. Hunter is known for his work in high-temperature metallurgy and his application of die casting techniques to higher melting point alloys. The award, consisting of a certificate, plaque, and cash honorarium, was presented at the Annual Meeting of the American Die Casting Institute, on Sept. 17th.

Jet-Piercing Developer Heralded by Franklin Institute

Robert B. Aitchison, developer of the Jet-Piercing flame process for obtaining iron ore from hard rock, will receive a John Price Wetherill Medal from the Franklin Institute on Oct. 21st.

The medal was awarded Mr. Aitchison "In consideration of his initiation, development, and practical application of the Jet-Piercing process as applied to open pit mining and quarrying and the economic importance of this development to the steel industry and to the nation."

With the 4300°F flame of the Jet-Piercing process, it is estimated that by 1975 more than 30 pct of the US supply of iron ore will come from taconite, low-grade iron bearing rock previously uneconomical to mine. Thermal-Texturing, a process for surfacing granite and other stone, is another of his innovations. In all, Mr. Aitchison has been granted 13 patents dealing with flame processes and equipment. He now holds the position of consulting engineer for the Linde Co., div. of Union Carbide Corp.

Magnetism Conference at Detroit Nov. 16-19

The Metallurgical Society of AIME will this year co-sponsor the Conference on Magnetism and Magnetic Materials, scheduled for the Sheraton-Cadillac Hotel in Detroit, Nov. 16-19. This Conference marks the fifth annual meeting sponsored by the American Institute of Electrical Engineers and interested societies. The Office of Naval Research, The American Physical Society, and The Institute of Radio Engineers are also participating in this year's Conference.

One of the items on the agenda for registrants is an exhibit of photographs relating to magnetism. Another is a magnetic products and instrumentation exhibit.

Further information may be obtained from *D. M. Grimes, Dept. of Electrical Engineering, University of Michigan, Ann Arbor, Mich.*

MEMBERSHIP

Proposed for Membership Metallurgical Society of AIME

Total AIME membership on Sept. 1, 1959 was 32,615; in addition 2,738 Student members were enrolled.

ADMISSIONS COMMITTEE

L. L. Seigle, Chairman; W. L. Brytczuk; F. B. Foley; T. D. Jones; Harold Margolin; Shadburn Marshall.

The Institute desires to extend its privileges to every person to whom it can be of service, but does not desire as members persons who are unqualified. Institute members are urged to review this list as soon as possible and immediately to inform the Secretary's office if names of people are found who are known to be unqualified for AIME membership.

Members

Armstrong, Raymond E., Jr., Newark, N. J.
Clarke, Herbert H., Latrobe, Pa.
Dunn, Edward J., Thomaston, Conn.
Hahn, Jack, Montreal, Quebec, Canada
Healy, Robert M., West Chicago, Ill.
Johnson, Lester E., Detroit, Mich.
Kleppa, Ole J., Chicago, Ill.
Lambertus, Harold N., Kansas City, Mo.
Loos, Richard W., Wintersville, Ohio
Oriani, Richard A., Monroeville, Pa.
Promisel, Nathan E., Silver Spring, Md.
Reinhardt, Gustav, Niagara Falls, N. Y.
Richardson, Frederick R., Holland, Mich.
Robinson, Raymond B., Los Angeles, Calif.
Ross, John W., Toronto, Ontario, Canada
Schroeder, Ralph G., Chicago, Ill.
Schussler, Mortimer, Lewiston, N. Y.
Sperry, Philip R., New Haven, Conn.
Troy, Joseph C., Jr., Pittsburgh, Pa.
Wallace, John F., Cleveland, Ohio

Associate Members

Fegredo, Desmond M., Berkeley, Calif.
Whitson, Richard E., Jr., Elizabeth, N. J.
Woods, Henry L., Jr., Middletown, Ohio

Junior Members

Barloga, Albert M., Hammond, Ind.
Dorney, Donald E., Reading, Pa.
Hicks, William T., Wilmington, Del.
Ho, Jack W., Palo Alto, Calif.
McCarthy, John J., Cambridge, Mass.
Nail, John B., Jr. Chicago Ill.

REINSTATEMENT—CHANGE OF STATUS

Associate to Member

Wilkins, Charles H., Cheswick, Pa.

Junior to Member

Nelson, Ralph L., Jr., Birmingham, Ala.

Student to Member

Mannweiler, Gordan B., Naugatuck, Conn.

SPECIAL REINSTATEMENT

Associate Member

Jemian, Wartan A., Greensburg, Pa.

RE-ELECTION

Member

Grant, George, III, Midland, Mich.

NECROLOGY

Date Elected	Name	Date of Death
1926	Allen, Horace J.	Aug. 15, 1959
1944	Estey, Arol W.	Unknown
1949	Utt, Ralph B.	July 21, 1959

OBITUARIES

Allen, Horace J. (member 1926) died Aug. 15th in Port Colborne, Ontario, Canada, at the age of 74. At onetime vice president of the Algoma Steel Corp., Sault Ste. Marie, Ontario, Mr. Allen came out of retirement 14 years ago to head the Canadian Furnace Company, Ltd., when Algoma purchased the Company.

EMD BYLAW CHANGE

Provision for an EMD Publications Committee was made at the June 22nd meeting of The Metallurgical Society's Board of Directors in the following motion: "The duties of the Publications Committee shall be to examine and review all papers in its field submitted to the Society for publication in TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME; to evaluate reader comment obtained on each paper; and to recommend to the Publications Committee of The Metallurgical Society as to acceptance or rejection of papers for TRANSACTIONS OF THE METALLURGICAL SOCIETY OF AIME. It also may assist the editor of JOURNAL OF METALS on the acceptance of papers in its field for publication." This bylaw revision was also approved by the AIME Board of Directors on June 23rd.

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Limited to AIME members, or to companies that have at least one AIME member on their staffs. Rates $50 per year per inch.

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Coming Events

Oct. 5, AIME, NOHC Chicago Section Fall Dinner Meeting, Phil Smidt's Restaurant, Hammond, Ind.

Oct. 5-6, 27th Annual Meeting of Engineers' Council for Professional Development, Wade Park Manor, Cleveland.

Oct. 7-9, Sixth National Symposium on Vacuum Technology of the American Vacuum Society, Sheraton Hotel, Philadelphia.

Oct. 8-9, AIME, NOHC Southwestern Section, Fall Meeting, Pere Marquette Hotel, Peoria, Ill.

Oct. 9, AIME, NOHC Eastern Section, 13th Annual Conference, Warwick Hotel, Philadelphia.

Oct. 11-16, Third Pacific Area National Meeting of the American Society for Testing Materials, Forum on Reactor Materials, Sheraton-Palace Hotel, San Francisco.

Oct. 14, AIME, Acid Converter and Basic Oxygen Steel Committee Technical Meeting and Plant visit, Algoma Steel Corp., Sault Ste. Marie, Ontario, Canada.

Oct. 16-17, AIME, NOHC Southern Ohio Section, Fall Meeting, Deshler-Hilton Hotel, Columbus, Ohio.

Nov. 2-5, Fall Meeting of The Metallurgical Society of AIME, Morrison Hotel, Chicago.

Nov. 4-6, American Nuclear Society, Winter Meeting, Sheraton Park Hotel, Washington.

Nov. 6, AIME, NOHC Pittsburgh Section, Off-the-Record Meeting, Penn-Sheraton Hotel, Pittsburgh.

Nov. 9-11, 14th Technical and Operating Conference, Steel Founders' Society of America, Carter Hotel, Cleveland.

Nov. 10, AIME, NOHC Buffalo Section, 10th Annual Meeting, Royal Connaught Hotel, Hamilton, Ontario, Canada.

Nov. 16-20, Conference on Magnetism and Magnetic Materials, sponsored by the AIEE, The Metallurgical Society, and others, Sheraton-Cadillac Hotel, Detroit.

Dec. 1-3, Symposium on Structural Changes in Metals and Alloys, co-sponsored by the Indian Institute of Metals and Dept. of Metallurgy, Indian Institute of Science, Bangalore, India.

Dec. 2-4, AIME 17th Electric Furnace Conference, Hotel Cleveland, Cleveland, Ohio.

Dec. 7, AIME Arizona Section, Annual Meeting, Tucson.

Jan. 11-13, 1960, Sixth National Symposium on Reliability and Quality Control in Electronics, Statler-Hilton Hotel, Washington.

Jan. 20, 1960, AIME, Second Conference on Flat Rolled Products, Del Prado Hotel, Chicago.

Jan. 25-29, 1960, Stress Measurement Symposium, sponsored by *Strain Gage Readings*, Arizona State University, Tempe, Ariz.

Feb. 14-18, 1960, AIME Annual Meeting, Hotel McAlpin and Hotel Statler, New York.

Feb. 16-19, 1960, Symposium on Hydrometallurgy, *Wet Processing of Minerals and Industrial Products*, The Australasian Institute of Mining & Metallurgy, Adelaide, Australia.

Mar. 9-10, 1960, Symposium on Processing of Materials for Re-entry Structures, The Mid-West Society of Aircraft Materials and Process Engineers, Dayton, Ohio.

Mar. 15-21, 1960, Third International Conference on Nondestructive Testing, Tokyo, Mar. 15-18; Osaka, Mar. 21.

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